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GREENLAND

Published by

THE COMMISSION FOR
THE DIRECTION OF THE GEOLOGICAL AND
GEOGRAPHICAL INVESTIGATIONS
IN GREENLAND

VOLUME I

THE DISCOVERY OF GREENLAND,
EXPLORATION AND NATURE OF THE
COUNTRY

COPENHAGEN
C. A. REITZEL
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LONDON
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OXFORD UNIVERSITY PRESS

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PUBLISHED AT THE EXPENSE OF THE
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CONTENTS

ERRATA

Page 237 l 13 from the top	read Ilímaussaq for Ilimaussaq
— 307 l 7 from the bottom	read Eskimos for Ekimos
— 308 l 9 from the top	read Qíngua for Kingua
— 308 l 9 from the top	read Tasermiut for Tassermiut
— 317 l 4 from the top	read Frederikshaab Iceblink for Frederikshaab, iceblink
— 350 l 2 from the top	read Homoptera for Hemiptera
— 353 l 19 from the top	read genera for families
— — l 20 from the top	read genera for families
— — l 6 from the bottom	read 78 for 20
— 432 l 7 from the top	add: Meinardus, W.: Die hypsographischen Kurven Grönlands und der Antarktis und die Normalform des Indlandseises. Peterm. Mitt. 1926.

PREFACE

In the summer of 1913 Louis Bobé, Ph. D. now Royal Historiographer and lecturer at the University of Copenhagen, and Ad. S. Jensen, M. Sc. now Ph. D. and Professor at the University of Copenhagen, prepared a plan for an "authoritative" work on Greenland, to commemorate the bicentenary of July 3d, 1721, the day on which Hans Egede, the first colonizer and preacher of Christianity, landed in the country. The object was to replace the meritorious but now somewhat antiquated works of H. Rink, *viz.* "Grönland" (1852—57) and "Danish Greenland" (1877) by a systematic description of Greenland and an objective account of its development under Danish rule, principally based upon the comprehensive researches carried on in Greenland during the last fifty years or so, the results of which had been made known, partly in the hitherto published volumes of "Meddelelser om Grönland," partly in other accounts of expeditions and voyages in that country. The work was also to serve as a practical guide for officials and travellers in Greenland, and it was intended to publish it with the collaboration of Danish explorers of Greenland and with the support of the Greenland Section of the Home Office (the "Royal Greenland Trading Company"), while expenses were to be defrayed by the Government and the Carlsberg Fund.

A detailed account of the plan was laid before the Greenland Section of the Home Office and the Commission for the Direction of the Geological and Geographical Investigations in Greenland. The Commission replied to the effect that, as early as 1906, they had taken steps towards realizing a similar plan, which had only temporarily been laid aside, and therefore they thought that this task devolved naturally upon them. As, however, the proposers had done a great deal of preliminary work, the Commission offered to publish the book under their joint editorship and that of two members of the Commission, Commander G. C. Amdrup, now Vice-Admiral in the Royal Danish Navy, and H. P. Steensby, Ph. D. and Professor of Geography at the University of Copenhagen. At the same time the Commission proposed, instead of a collective work, to publish two separate works, *viz.* a Danish and an English one, the former principally containing geographical-topographical-historical descriptions of the districts of Greenland, the latter a scientific, monographic report on the geography and history of the country.

The proposal of the Commission was accepted, and in 1913 the editing committee met together. Professor Steensby was made chief editor, and he prepared the plans for both works, the idea being to compile them simultaneously.

In the general disturbance caused by the Great War, however, this plan was also upset. The publication of the English work was postponed for the time being, and only under great difficulties did it prove possible to complete the Danish work in time. In the midst of the preparations for the work Professor Steensby died, and on his death (1920) Dr. Bobé became chief editor.

It was not until two years after the appearance of the Danish work "Grönland i Tohundredaaret for Hans Egedes Landing," that the preparations for the English work were resumed. Since Professor Steensby's death his successor at the University, Professor M. Vahl, had become a member of the Commission for the Direction of the Geological and Geographical Investigations in Greenland, and he also joined the editing committee as chief editor of the English work, the three other members being the same as those in the Danish committee, *viz.* G. C. Amdrup, Vice-Admiral, Dr. Louis Bobé and Professor Ad. S. Jensen.

The cost of publication of the present work "Greenland" in three volumes has been defrayed by the Carlsberg Fund, for which the undersigned take this opportunity of expressing their sincere gratitude.

Throughout the work the metrical system has been used. The proofreading as regards the Greenlandic words and names occurring in the text has been undertaken by the Rev. H. Ostermann, formerly rector at Jacobshavn in Greenland, now at Greve in Denmark.

Copenhagen, January 1928.

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EARLY EXPLORATION OF GREENLAND

BY

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Historiographer Royal of the Danish Orders of Knighthood.

The first news of Greenland to reach Europe after the communication between the northern countries and the once flourishing Norse settlements had been broken off, originates, as far as is known, from the expedition which, encouraged by King Alfonso of Portugal, King Christian I sent out "towards the north with the view of discovering new countries and islands."

The contact between Denmark and Portugal goes back to the early half of the 15th century, and is naturally first inaugurated by the relationship existing between the two royal houses, Prince Henry of Portugal, known by the name of the Navigator, being the cousin of Queen Philippa, the queen of King Erik, the predecessor of Christian I. At the request of the Danish King, Claudius Clausson Swart of the island of Fuenen prepared a description of the northern countries in which Greenland is mentioned, and where the possibility of reaching China by sea from Norway is set forth. This work probably attracted the attention of the Infante, whose far-seeing, deliberately working spirit paved the way for the great tasks which were only carried out after his death, and in this suggestion he possibly saw a glimmer of hope for the accomplishment of his chief object, *viz.* the discovery of the north-west passage, with the support of the northern kingdoms and experienced navigators from those parts. Further evidence of the continued contact between Portugal and Denmark is the honourable reception accorded in Lisbon and Sagres to the Danish nobleman Vollerts (Vollert or Volrad) and his appointment as leader of the expedition to Africa, sent out in 1448 by Henry the Navigator, as well as the request addressed to King Christian I by the Infante or King Alfonso to let a man of his court take part in the planned conquest of Alcazar. The Danish King sent the pursuivant Lolland, but before his return, in 1461, with a royal letter to his king from Alfonso, containing honourable mention of his brave conduct during this campaign, Henry the Navigator was dead.

Several years passed before the contact between the Portuguese and the Danish royal houses was renewed, but in 1472 or 1473 King Christian,

presumably in accordance with earlier promises to King Alfonso, sent out an expedition to the most northerly seas.

The principal source of information as to this expedition is a letter found (1909) in the Danish State Archives by the present writer. It is addressed to King Christian I by Carsten Grip, burgomaster in Kiel, who writes that a map recently published in Paris mentions how the two skippers, Pining and Pothorst (sent out by King Christian I at the request of the King of Portugal), had erected a beacon on the rock Hvitserk "off Greenland over against the Snäfelljökull on Iceland towards the sea," and that they had been attacked by the Greenland pirates (the natives) in many small boats without keels.

Through a series of investigations undertaken by A. A. Björnbo, Fridtjof Nansen, Gustav Holm and especially Sofus Larsen, the value of this addition to our knowledge of the history of pre-Columbian voyages has been thoroughly estimated and worked up in connection with the other detached reports on the same expedition[1].

As the result of these investigations it has been proved beyond a doubt that an expedition was sent out by the King of Denmark in 1472 or 1473, and that King Alfonso strongly encouraged the undertaking. As leaders of this expedition were appointed the two adventurers, Diedrick Pining, who was probably already at that time in the confidence of the Danish King, and Hans Pothorst, whose name and coat of arms have been brought to light on a fresco painting in St. Mariæ Church, Elsinore. Pining went ashore at the rock Hvitserk, which must be looked for in the region round Angmagssalik on the east coast of Greenland, and here he engraved a compass as a beacon, resembling the one engraved by him in the rocks of North Cape, after his appointment as Governor at Vardöhus (Finmarken), and his crew had a hostile encounter with the natives of the country. On this expedition Pining and Pothorst were further joined by the Norwegian Johannes Scolvus (?—Skalp meaning a man living on the coast in the northern part of Norway) and a Portuguese nobleman, João Vaz Cortereal (the father of the well-known explorer Gaspar Cortereal, who in 1500 and 1501 undertook two voyages to the tracts round Davis Strait).

[1] Louis Bobé: Danske Magasin 5 VI 304, 6 I 383, Medd. o. Gr. LV 5 f. A. A. Björnbo og Carl S. Petersen: Der Däne Claus Claussøn Swart 1909 247 ff., Fridtjof Nansen: Nord i Tåkeheimen 1911 383, A. A. Björnbo: Medd. om Grønland XLVIII, 14, 257, 271, Gustav Holm: ibib. LVI, 297, Sofus Larsen: Aarb. f. nord. Oldkyndighed 1919, 265 ff. Edv. Bull: Det Norske Geogr. Selsk. Aarb. 1919, 21, 39 and Sof. Larsens rejoinder in Grønl. Selsk. Aarb. 1922, 72 ff. Sofus Larsen: La Découverte du Continent de l'Amérique septentrionale en 1472—73 par le Danois et Portugais (Coimbra 1922), — Conférence faite au XXI Congres international des Américanistes 1924, Göteborg 1925. — Sofus Larsen: The Discovery of North-America twenty years before Columbus, Coph. & Lond. 1925, Dsk. Geogr. Tidsskr. 28 Bd. 2 H. 1925.

It has also been proved that this expedition, in its further course, had some bearing upon the discovery of the North American Continent, as it seems likely to suppose that Columbus on his journey of 1476 (curiously enough the same year which is given in several sources for Scolvus' voyage to Labrador, under the auspices of King Christian I) met with and obtained information from Icelandic skippers to the effect that Danish vessels had made land on the other side of the North Atlantic, and that this knowledge contributed towards the maturing of his plans for the renowned voyage of 1492.

From the same year when Columbus landed on the West Indian shores dates a papal brief, communicating that no news had been had for a long time of the Norse settlements in Greenland. It is further stated that this country has not been navigated during the last eighty years, that the inhabitants, whose manner of living is described, have fallen from their Christian faith and have no other memory of their worship of God than an altar cloth which was used by the last bishop a hundred years ago when consecrating the sacrament, but which now only once a year is shown to the people. The Benedictine monk, Mads Knudsen, who had volunteered to search for the country and lead the inhabitants back to their Saviour was, by the Pope, appointed Bishop of Greenland. However, no information is at hand to show whether his plans have been carried into effect.

The existence of the old Norse settlements at such a late period as indicated in this statement is confirmed by the important discoveries made in 1921 by Dr. P. Nörlund, in the course of excavations undertaken in the old Norse churchyard at Herjulfnes (Ikigait) South Greenland, *inter alia* by means of the cut of the grave clothes brought to light, although, judging by the skulls and other skeletal parts found, the descendants of the original settlers must at that time have been a degenerated race[1].

At the beginning of the 16th century the Archbishop of Trondhjem, Erik Walkendorff, collected all the sailing directions for Norway and Iceland, which for more than two hundred years have been a valuable source of information, partly for those who for practical purposes desired to reach the country, and partly for those who made scientific attempts to identify the old Norse settlements, the so-called "Erik's route," the passage right across from Bredefiord to Hvitserk, and then along the shore round Hukken (i. e. the hook) to Erik the Red's settlement in Eriksfiord. In the year after his accession, 1514, King Christian II applied to the Pope that absolution should be granted to the sailors taking part in a projected expedition to the Arctic Sea. Events at home, however, caused the project to be abandoned for some time, but in the summer of 1519 it had matured

[1] Medd. om Grönl. LXVII: Syn og Sagn, 1925, 12 ff. 69 ff. Fra Naturens Verden, 1925, 98 ff.

so far that the King had resolved to "reconquer with a mighty fleet the city of Gardar from the hands of the infidels," on which occasion Leo X granted the King's request to have his confessor, Vincentius Pedersen Kampe, nominated Bishop of Gardar. As leader of the expedition was appointed Sören Norby, and, after the subjugation of Sweden, King Christian wrote to him, in December 1520, that he should make his ships ready for the expedition to Greenland, to which Sören Norby answered in February the following year that, owing to untoward circumstances, he could not be ready till after Easter. Shortly afterwards a rebellion broke out in Sweden, and Sören Norby was fully occupied in fighting the mutinous East-Gotlanders.

The interest felt by King Christian in the recovery of Greenland was further encouraged by his chancellor, Klaus Pedersen, who lived in Rome from 1521 to 1522, and who in a letter written the previous year reminded his king of the importance of attempting navigation from Denmark to India and other hitherto unknown countries, which task more rightly fell upon him than upon the Spaniards, who in their voyages drew nearer and nearer Greenland. Sören Norby was not destined to lead the purposed expedition to Greenland, but as late as 1528 he wrote to his master that he had not abandoned the thought of recovering the two Greenland bishoprics, held by the Grand Duke of Russia, together with part of Norway, from which it appears that the country in question is not identical with the old Greenland.

Immediately after the death of Frederik I the interest in Greenland seems to have revived. In the notes of Vincens Lunge from August 28th, 1533, regarding various matters which were to be dealt with by the supreme national council in Romsdalen (Norway), Greenland is also mentioned.

Twice, in 1537 and 1539, Hamburg sailors on their voyages to and from Iceland had been driven towards the coast of Greenland, and on the latter occasion they had been quite close to the shore, only a gunshot distant, though they had been prevented from reaching it by storms and bad weather, and this led to the sending out of a caravel from that city, with the object of searching for Greenland. The skipper, who was called Gert Mestermaker, found the country, but could not catch sight of the inhabitants, and so he returned without success. These reports may probably be connected with the information given, about 1560, by Jon Greenlander, an Icelander, who was said to have been called by that name, because he had three times, together with other sailors, been blown off to Greenland and could tell a good deal about it. On one of these voyages they had found a deep fiord, extending far into the country, with many islands sheltered against storms and seaway. There they had anchored, and he had been ashore and found a dead body, whose knife he had appropriated.

Of other information relating to Greenland from those years there is only the note communicating that Christopher Huitfeld, who from 1541

to 1543 was Governor of Iceland and from 1542 to 1546 of Bergenshus, in the year 1541 brought back to Norway old sailing directions, written in Latin and Norwegian, or, as it was termed, "a chart for the navigation of Greenland." From the reign of Christian III there is an undated letter from Peter Huitfeldt, the Chancellor of Norway, containing a first draught of a Royal Grant issued to him and Christopher Walkendorff, Dean of Bergen and Governor of Bergenhus, and authorizing them to search for and exploit Greenland, in return paying the King, as "from time immemorial they are under obligation towards the Crown of Norway."

In his writing "Om Norges Rige" (1567) Absalon Pedersen expressed the discontent felt by himself and others at the lack of interest shown towards the plan of re-discovering Greenland. All states ought to help Norway, so that a country belonging to the Norwegian crown should not be ignominiously given up. Absalon Pedersen was unable to indicate the position of Greenland, beyond the information given by the cosmographers that it was connected with America. He did not know that Greenland had been discovered from Iceland, or that for several hundred years it had constituted a community independent of Norway. To him Greenland was only an old Norwegian tributary, and this view is also adopted by Claus Lyschander, as well as by Hans Egede and many later writers.

About the middle of the century attempts were made on the part of England to find a shorter northern route to India, which might take the place of the well-known long way round Africa. For this purpose an expedition was equipped and sent out from London, the famous navigator Sebastian Cabot being one of its chief promotors. Whereas the leader of the expedition, Sir Hugh Willoughby, with two vessels sailed aimlessly to and fro in the Arctic Sea, and at last sought shelter in a harbour on the boundary of Norway and Russia, where he and his crew succumbed to the hardships of the Arctic winter, the third vessel, commanded by Richard Chancellor, who had missed the meeting place of the vessels (Vardö), by a lucky chance reached the White Sea and anchored at the mouth of the Dwina. The result of this expedition was a treaty between Czar Ivan IV and the Queen of England, which treaty paved the way for a flourishing, profitable trade, to the detriment of the Danish Sound Duties.

In the general vagueness of ideas as regards the position and outline of Greenland which prevailed in those days, presupposing, as they did, that Greenland was connected with the northern countries, and that its name after 1557 was used to denote Novaja Zemlja, we find the explanation of the fear entertained by Absalon Pedersen and other contemporaries that Greenland should be invaded by the Russians, as well as of the view set forth by Carsten Grip that the connection by land between the new world and Greenland constituted another danger for the supremacy of the King of Denmark and Norway from the Portuguese and Spaniards.

Throughout the whole of his reign, even during the seven years' war with Sweden, King Frederik II made one attempt after another to maintain the right of the Danish crown to the lost colony of Greenland, and expeditions were sent out to the Arctic Sea, mostly with the assistance of English pilots who were familiar with navigation in the Arctic.

In the spring of 1568 Jürgen Teigsen, an English sailing master or pilot, who had been recommended to the King as an experienced and able navigator and traveller, was given a promissory grant which secured him a considerable pension for life, free lodging in Copenhagen and various emoluments in kind if he succeeded in finding the lost Greenland. He was to be furnished with a proclamation to the natives, a curious mixture of the Danish and Icelandic tongues, but a few days after the issuance of this proclamation the King abandoned the project, as the war with Sweden made it necessary to use elsewhere the ships set apart for the expedition of Teigsen.

Greenland was unwittingly discovered by the English when, in 1576, Martin Frobisher sighted the east coast in lat. 61° N. and circumnavigated the south point. On his third voyage, in 1578, he landed somewhere on the south-west coast, of which he took possession in the name of the Queen of England. As he travelled by the map, published in 1558 by the Zeni, he thought that it was the imaginary island of Friesland, which had been included in this map.

The voyages of Frobisher caused Frederik II to enter into negotiations with the Scotchman, James Allday, who had made several voyages to Iceland and the White Sea, and who thought himself capable of finding Greenland. In 1579 Allday arrived in Copenhagen via Lübeck, where he had published a small guide for navigators, translated from English into German, and in May the King gave orders for the equipment of two vessels, manned with able and courageous sailors who knew the route to Iceland. The object of the expedition was to search for the colony of Greenland, which had not been visited for many years, so that the latter, which belonged in justice to the Norwegian crown, might once more come under its lawful government, and the natives be reconverted to the Christian faith. Allday sailed from Copenhagen via Bergen and north of Iceland, from which it appears that he cannot have been familiar with the old sailing directions, which from Bergen indicate a route south of this island; and in the month of August he made several attempts to reach the east coast, according to a diary from the journey probably the region round Angmagssalik, where only a narrow belt of ice divided him from the shore. Though this voyage had been undertaken at the season which is most favourable for the navigation of the east coast, Allday, after his return, set forth the opinion that there would be a greater chance of being able to land if the attempt was made in the spring. He succeeded in winning the King to this

project, for in November an order was issued for the equipment of two vessels to be sent to Greenland during the following spring, but in June, 1580, the King, for what reason is uncertain, determined that the two galliots which should have been used for that purpose, were to be sent elsewhere.

In 1581, however, the King made a new attempt at the re-discovery of Greenland, in that he accepted the offer of the well-known adventurer, Magnus Heinesen, to search for the country, "at his own cost and risk," with two vessels. Magnus Heinesen, who apparently followed the same route as Allday from Bergen towards the west, likewise failed in the attempt, for although he got sight of the east coast of Greenland, he was prevented by drift-ice from reaching the shore.

In 1582 the King had a favourable opportunity of discussing his Greenland projects with the greatest authority of those days, Frobisher, who came to Copenhagen with the English embassy, which was to present King Frederik II with the Order of the Garter. It is said that the King was so impressed by the accounts of the great Arctic traveller, his noble character and natural intelligence, that he applied for the consent of Queen Elizabeth to let Frobisher enter his service. The answer of the Queen is not known, but the hope of the King was at any rate not fulfilled.

In the following year the King entered into negotiations with the energetic, but already aged Olivier Brunel from Brussels, who for a long time had carried on contraband trading with Siberia and the land of the Samoyedes. Brunel and his partner, Arent Meier from Bergen, received a promise of the monopoly of the Greenland trade if they could find the country. As the chief object of the expedition is again given the preaching of the gospel, but nothing came of the plan, any more than of the preceding ones. A few years afterwards the English again succeeded in setting foot in Greenland, and during his voyages in 1586 to 1587 and 1588 John Davis landed in several parts of the west coast, however, like Frobisher without identifying the country with the old Greenland.

On his first voyage John Davis sighted the south point of Greenland and called it by the name of Cape Farewell, because he could not come near the land by 6 or 7 miles for ice. When subsequently he sighted the coast in lat. 61° N. he realized that this country could not be Friesland, as it was so far from the Engroneland of the Zeni, and he called it the Land of Desolation and the northern part London Coast. As Frobisher's accounts of his travels do not contain determinations of longitude, Davis referred the localities discovered and named by the latter to this coast, for which reason he let Frobisher Strait, situated north of Labrador, pass right through Greenland at Sermilik, and placed an island south of the strait, which he called by the name of Reg. Elisabeth's Foreland. On the north side of the strait he placed Frobisher's Meta incognita, his own Desolation and London

Coast, as is shown on Molyneux' globe from 1592 and the new map of 1600. The error is repeated in Hudson's (1612) and other maps, where Friesland is placed in lat. 62° N. east of Desolation and close to Cape Discord on the east coast of Greenland. Davis penetrated farther into the strait called after him (Dutch: Straat-Davis), and during the latter part of July, in lat. 64° 15′ N. or at the mouth of Godthaab Fiord, he entered the later Ball's River, which in honour of the family Gilbert, his friends and neighbours in his native place Sandridge, he called by the name of Gilbert Sound[1].

Davis traded with the natives, of whom he gives a detailed and sympathetic account. On his second voyage, in the following year, he was again in the same region, and this time he again entered Ball's River, where among snow-clad rocks he found a grass-covered plain which he likens to the large meadows in England. He once more gives a detailed account from this part, the oldest one preserved, of the costumes and habits of the Greenlanders, and he enumerated about 40 words of their language.

King Frederik II was undoubtedly greatly interested in the news of the voyages of Davis, while at the same time maintaining his relation with the admired Frobisher, from whom we have a letter, written to the King in 1587, in which he thanks him for his constant favour and protests his readiness to serve him. The bearer of the letter, a Dane, will by word of mouth render an account to the King of his last dangerous voyage.

Like his father, Christian IV[2] took a lively interest in the recovery of Greenland. As early as at the time of his accession he is seen to have made a draft of an agreement with the adventurous nobleman, Erik Lange of Engelsholm, who had ruined himself with alchemy. With the assistance of Dutch skippers the latter engaged to take possession of the countries "Grønland and Gronlandt" which had already been discovered, but were not yet open to communication. These negotiations failing, Erik Lange, in 1592, undertook a similar obligation towards Duke Frantz II of Lauenburg[3], and at a later period King Christian IV took steps towards the re-discovery of Greenland by sending for expert English navigators as captains, pilots or navigation-masters who had been on the expeditions of Frobisher and Davis or other travellers in the Arctic Sea. The first expedition sent out by King Christian IV comprised three English navigators: James Cunningham from Scotland, who in 1603 had served as a captain in the Danish Navy, John Knight and James Hall; of the latter it is known that he had been

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[1] William Barent's map from 1596 shows the following English names in Greenland: Along the northern side of the imaginary Frobissher Strait: Cape Desolation, Warwykes(?) Bersound, Lockersland, Warwickes forland.

Along the west coast of "Fretum Davis": L. Darcies, Marchant S., Base bartier, London Cost. Hope Sanderson.

[2] C. C. A. Gosch: Danish Expeditions, 1605 to 1620. Vol. I—II. London 1897.

[3] Ztschr. des hist. Vereins f. Niedersachsen 1879, p. 281.

before "to Friesland and other neighbouring lands towards America" as it is said in Lyschander's "Grönlandske Chronica."

Of the three vessels equipped for the expedition "Trost" was commanded by Cunningham, with Hall as a pilot; "Den röde Löve" (in all probability the same vessel as "Red Lion" from Hall's third expedition) was commanded by the nobleman Godske Lindenow of a well-known Danish family, with the Dane Peter Kieldsen, who had formerly taken part in whaling expeditions, as a mate. The third vessel "Marekatten" was commanded by the Englisman John Knight. The expedition left Copenhagen on May 4th, 1605, and with a favouring east wind Hall shaped his course between the Orkneys and Shetlands past Fairhill. Not far from the southern extremity of Greenland the vessels were caught in a storm, and "Trost" lost sight of "Löven" and "Katten." As the weather cleared up, Hall sighted land in lat. 59° 50′ N., and together with Cunningham he called the jagged promontory, probably the west coast of Eggersö, by the name of Cape Christian, and so it is called to this day.

On the following day Cunningham sighted the two other vessels. Lindenow came on board "Trost," and earnestly requested Hall to furnish him with a chart so that they might be able to proceed if they should again be separated. According to his own account Hall now attempted to sight Cape Desolation, from which and several other facts it appears that he must have known the geographical results of Davis' expeditions. For eleven days the vessels tried in vain to get clear of the ice, and then a dispute arose between the English commanders and Lindenow, the result of which was that the latter stood off from the two vessels and sought a harbour, possibly either the so-called "Dutch Harbour" in Qilángait Bay, between Skinderhvalen, Íkátoq and Nukarît, or the harbour of the same name at Fiskenæs, which before the days of Egede was used as an emergency harbour. Lindenow and his men met with the natives, and by bartering became possessed of bear and fox-skins as well as narwhale tusks.

Having secured these things and two Eskimos, who had been carried away by force, Lindenow thought that his task was so far accomplished that he could sail for home and, by anticipating the Englishmen, enjoy the first fruit of the favour of King and people as the first Dane who for centuries had set foot on Greenland soil. After only seventeen days at sea Lindenow arrived in Copenhagen, on Aug. 28th, and was given a splendid reception. The King and Queen came out to visit him on board "Trost," and all Copenhagen crowded down to the harbour, which was richly decorated with flags.

The actual results of this forced trip were, however, far less valuable than those subsequently shown, when at the beginning of October Cunningham and Hall reached back in safety. After the separation of the vessels Cunningham had headed midway between Cape Walsingham and Simiutaq

towards the ice-free coast, where he saw a jagged, sharply pointed mountain range between the two outstanding promontories; the southern of these (which is identical with Kangâtsiaq) he called Queen Anne's Cape in honour of the Queen, the northern, Kangârssuk (67° 4′) Queen Sophia's Cape after the Dowager Queen, while the tallest peak along the rocky shore, the 990 m high Qáqatsiaq (66° 35′), was called Mount Cunningham after the commander of the vessel.

On June 12th the vessels entered Itivdleq (66° 33′), which was given the name of King Christian's Fiord, and here they remained and took possession of the country in the name of the King of Denmark. They first anchored by an island inside the promontory on the north side (Itivdleq's outpost or Itivnera), where Hall parted from Cunningham. He was no sooner left alone on the small vessel commanded by him, than he was attacked by the natives with a shower of arrows and stones, and so he sought a good harbour, which he called Danmark's Harbour, close to the western extremity of the elongated peninsula Tunúngassoq. From there he went in a northerly direction into the fiord South Kangerdluarssuk, which he named Cunningham's Fiord. The sounds between the islands in the fiord he called Kattesund, Grønsund and Musling (i. e. mussel) Sound, respectively. After a few days' stay he headed into a large fiord, which was called Pustefiord and is undoubtedly identical with Isortoq, throughout the 18th century known by the name of Pustefiord, although during Hall's later stay in the same locality it was named Prince Christian's Fiord. Then he headed into Ataneq Fiord, which in honour of the then Governor of Copenhagen was called Breide Rantzau's Fiord (in the maps altered to Brede Ranssom Fiord). Hall's most northerly point was Sarqardleq (68° 35′), named Christen Friis Cape, and so he must be supposed to have seen Disko Bay and Disko Island. On his journey back Hall headed inside Rifkol, through Hamburger Sound, and also into Amerdloq—after Henrik Ramel, Councillor of the Realm, called Ramel's Fiord—and Ikertôq (Skagbofiord) where he erected three cairns.

Assisted by an ingenious system of cairns, which had been agreed upon beforehand, Hall on July 7th regained Cunningham, who lay at anchor close to Danmark's Harbour, and from there the two vessels set sail for home.

The geographical results of Hall's voyages are known from his own report, which is only preserved in an abbreviated form, and a map of the traversed distance from lat. 66°—68° 35′ N.; besides, there are three special maps of King Christian's, Cunningham's and Breide Rantzau's Fiords with inserted sounds, islands, harbours and rocks, nearly all identifiable, as well as a couple of land sights.

The proud exploit of Hall was commemorated by a map designed in 1605 by Bishop Hans Poulsen Resen and dedicated to the King, and in the

following year his example was followed by Bishop Gudbrand Thorlacius, to whom the first fairly accurate map of Iceland is due, presumably prepared for the use of his learned countryman Arngrimur Jónsson, whose description of Greenland for many years remained unprinted[1].

From this voyage of exploration, carried on under the Danish colours, though the honour was principally due to the Englisman James Hall, the *re-discovery of Greenland* must rather be dated. Everywhere in Europe the news caused a certain stir and through the nuncio at Brussels even reached as far as Rome.

Encouraged by these results the King decided to send out a new expedition in the following year, the cost being defrayed by a special tax, for which the consent of the Council had been obtained. This expedition consisted of five vessels, with Lindenow in supreme command, Cunningham, Hans Bruun, Carsten Richardson (from Flensborg) and Andreas Nolck as commanders of the remaining vessels, and James Hall once more as a pilot. This time he made a wide curve to avoid the west ice off the coast of Greenland, so that on two occasions he sighted America (Labrador and Cumberland Island) and then entered South Kangerdluarssuk, where on his first voyage he had found a mountain containing, he believed, valuable silver, presumably the same which Glahn in 1768 calls the "lead ore mountain" at Kangerdluarssuk.

By the order of the King two vessels were filled with this mineral, which, however, on further assays after the return of the expedition, turned out to be entirely valueless.

Although Christian IV in his disappointment at this result called Greenland the "Philosopher's Stone," he nevertheless determined to send out a third expedition, consisting of two vessels, commanded by Carsten Richardson and Guttorm Nielsen, a native of the Faroes, and with Hall as sailing master.

In the letter of instruction given to the commanders of the expedition reference is made to a revised edition of Ivar Baardsön's description of Greenland, as far as the place-names are concerned with many corruptions, in respect of which they were to sail from Cape Lindesnæs by a W. N. W. course towards the southern extremity of Greenland in lat. 60°—61° N. "albeit on the east side" that they might make an attempt to find Eriksfiord, where the best land and people of Greenland were to be found. They were to look for the localities mentioned by Ivar, and as no one entertained any doubt that the population of those parts were the descendants of the old Norse settlers, an Icelander and a Norwegian joined the expedition in order to be able to hold converse with them, while the sailors were earnestly requested to treat the Greenlanders with the greatest friendliness.

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[1] Arngrim Jonæ Liber de Grönlandia. Old Royal Coll. 4to 2876 (Royal Library at Copenhagen).

This expedition, like so many others before and after that time sent out with the view of reaching the east coast and, furthermore, at an unfavourable season, seems to have returned without accomplishing its object.

After his return from this voyage Hall, with the title of "His Majesty of Denmark's Pilot," lived in Elsinore, presumably until 1612, when he once more left for Greenland, this time not sent out by the Danish King, but as leader of and partner in a trading expedition equipped by a syndicate of "Merchant Adventurers of London," such as Sir George Lancaster, Sir Thomas Smith, Richard Ball and William Cockayne, and with no outrivalling Danish nobleman or sailing master. The expedition, which consisted of two vessels, was joined by William Baffin, the then unknown, but subsequently so famous Arctic explorer, who, like the quartermaster Gatombe, has left an account of the voyage, the object of which was partly to establish trade with Greenland and partly to exploit the above-mentioned silver mine, in which Hall still believed.

On May 14th Hall sighted the southern extremity of Greenland, which he supposed to be Cape Farewell, called so by John Davis on his first discovery of the country, because he could not come near the land by 6 or 7 miles for ice. The name, however, does not occur in the accounts of Davis, in which there is only the following statement relating to the second Greenland journey in 1586, *viz.* that on June 15th he discovered land in lat. 60° N. and long. 47° W. but was prevented from going ashore, as the ice formed a belt, lying 10—20, nay, as much as 50 miles off the shore. There are certain facts which point to Hall having obtained his knowledge of Greenland as a member of the above-mentioned expedition of Davis. He sailed up through Davis Strait and took a sight of "Tindingen" (Kingigtorssuaq), which Gatombe called by the name of Cape Comfort (lat. 61° 33′ N.) and this tract—the most pleasant and inviting in Greenland—he called "Land of Comfort" as contrasted with Davis' Land of Desolation. On May 27th Hall came to land in lat. 64° N., judging by the map in the exact locality of the present Falting's Harbour, which he called the Harbour of Hope, the same name being given by Hans Egede about a hundred years later to his anchorage in the immediate vicinity. Neither the Danish King nor Danish noblemen were now commemorated in the names given to the newly discovered localities. Hjortetakken (i. e. the antler), the beautiful mountain near Godthaab, he called Mount Hatcliffe, either Hartcliff (hart's peak) or rather Ratcliffe, the famous port of call in the Thames, from which Frobisher had started in 1576, and the great mountain north of Godthaab he called Mount Gabriel, in all probability after Frobisher's vessel, the "Gabriel," which a certain Christopher Hall, perhaps the father of James Hall, had commanded on the first expedition of Frobisher. The arms of the Godthaab Fiord (Davis' Gilbert Sound) he called Lancaster River (Ameralik Fiord) and Ball's River, which name it bears to this day. The archipel-

ago north of Godthaab Fiord (Satsigsuaránguit) he called Wilkinson's Islands after a merchant who was on board the vessel. Between the islands along the shore Hall and his followers rowed in a northerly direction to South Isortoq, which he called Cockinsfiord, a name occurring in all older maps, and anchored at Sukkertoppen (Manîtsoq). Across the dangerous South Strömfiord he reached the well-known localities Itivdleq and South Kangerdluarssuk with the "Silver Mountain." His crew shared his hopes that great wealth was in store for them, but their illusions were rudely shattered when the London goldsmith who had joined the expedition declared, like his Danish colleagues, that the bright metal was merely Muscovy glass or common mica. After this disappointment Hall rowed up into the Amerdloq Fiord, where he was killed by the dart of a Greenlander. He was buried on one of the outer islands, and as late as in the Greenland map of 1832 his grave is indicated, presumably, however, only according to conjecture.

On his voyages Hall roughly investigated and mapped the west coast of Greenland from the region round Godthaab to Egedesminde, and the memory of his courageous and able navigation is still preserved in the geographical names which owe their origin to him and particularly occur in the English Admiralty maps. That his determinations of places have been of great value as a guide for subsequent Greenland expeditions is beyond a doubt. His voyages to Greenland, undertaken for the King of Denmark, formed, together with the ancient history of the country, the basis of the "Grönlandske Chronica", a popular composition in verse, written in 1608 by the clergyman Claus Lyschander, which as far as the latest voyages are concerned contained information not to be found anywhere else.

With James Hall cease the Anglo-Danish voyages of discovery to Greenland, and the Dutch now take the lead as regards knowledge of the Arctic seas. A rapidly increasing number of trading expeditions to hitherto unexplored Arctic regions were undertaken under the auspices of the States General. In 1614 the so-called "Noordsche Compagnie" was granted a concession for fishing and trading "on or to the coasts between Novaja Zemlja and Straat Davis, including Spitzbergen and Bear Island." As to the right of carrying on whaling at Spitzbergen a quarrel sprang up between Denmark, Norway, England, the Netherlands and France. Whereas Christian IV, as the King of Norway, maintained his presumed right of possession of Spitzbergen as making a part of the dominion of the King of Norway, the Greenland of the old Norsemen, the other countries pleaded international law and priority of discovery. Although, after the circumnavigation of Spitzbergen, it had been realized in Denmark that this country could not be part of the east coast of Greenland, Christian IV officially maintains that Greenland, according to his conception, comprises all the countries north of Iceland and North Cape, while in 1631 he speaks of the Greenlandic island Spitzbergen, and Frederik III twenty years later mentions "the whaling beyond

lat. 67° N. off our country Christiansborg or Greenland or Spitzbergen." Consequently, the Greenland companies of the 17th century as a rule have nothing to do with Greenland, except when their privileges make express mention of Straat Davis, the name used about the coasts washed by the waters of this strait, and particularly West Greenland. Hans Egede mentions the "west side of Greenland which is called Straat Davids," and as late as 1770, in G. von Santen's list of whalers, a distinction is made between Greenland (Spitzbergen) and Straat Davis. The east coast of Greenland, to which the old Norse "Österbygd" was referred, is described as the old Greenland.

In the same year that the Noordsche Compagnie was founded, a ship was sent out to Davis Strait under the command of the excellent "navigator" Joris Carolus from Enkhuisen, who as a pilot on Dutch whaling ships in 1614 penetrated as far as the Vajgat. This name, which here occurs for the first time, is of Dutch origin, formed of *gat* (opening) and *weyen* (blow). In "Het niewe vermeerte Licht des Zeewarts," the widely known chartographic work, published by Master Joris in Amsterdam, 1634, it is said that "the country Oud Greenland extended towards the south to Cape or Staten-Hoeck and round the latter along Fretum Davids and into the large mere beyond which there is everywhere firm land, which I found in 1614, when I penetrated as far north as 73°." In 1616 Cumberland discovered Iceland, and in the same year Dutch skippers, in the name of the States General, took possession of the stretch between lat 60° and 66° N., which they called Statenland, and which for a period of four years was included in the concession of the company. In the following year Joris Carolus was off the east coast in lat. 66° N., where he bestowed the name of Enckhuysener Eyland on an island, perhaps Dannebrogsøen, and in the map of the west coast his name was for a long time preserved in the so-called Joris Bay in lat. 61° N. Joris Carolus also discovered New Holland, part of the east coast of Greenland between lat. 60° and 63° N., and in 1619 Christian IV took him into his service as teacher of navigation for the mates and sailors of the Navy.

The Noordsche Compagnie was exposed to keen competition on the part of private merchants. In 1624 Dirck Leversteyn of Delft reported to the States General that the ship sent out by him had discovered a land yielding a secure hunting ground and extending from the eastern cape of Fretum Davis as far as five degrees of latitude farther north. In all probability he is here thinking of the northern Fiskefiord (Atangmik) with Delftshaven, which by Joris Carolus was laid down in a map from 1636 and called by this name as late as the time of Egede. At the same time it was also reported by Engelbert Pietersz van der Zee in Briel that in 1624 and 1625 he had sent out ships to Straat Davis, with Marten Arendszen as a skipper, and that these voyages had led to the discovery of a new island with gold and silver mines. From this voyage dates the Cape Briel (Frede-

rikshaab) laid down in lat. 62° N. in the map of Joris Carolus, and Briel's Haven in lat. 63° (at Fiskenæsset). In the first letter of instruction issued in 1721 by the Bergen Greenland Company to the skipper who was to go up with Egede, Briel's Haven is mentioned as the harbour in which he was to be landed[1]. The States General summoned the Company as well as its competitors for the further substantiation of their discoveries, but as all the three parties seem to have been interested in sending out separate expeditions to the country, the matter was dropped for the time being. In 1625 the company equipped a vessel with the object of investigating a passage (Cumberland Bay) which had been searched for by Leversteyn, but their progress was stopped by the land, and they subsequently arrived at the strait which had already been discovered by Frobisher and called after him. Leversteyn forestalled the company by dispatching three ships to trade with the newly discovered countries and to look for a passage. They only found what had been known for a long time, *viz.* that Straat Davis actually existed and had a native population.

The part played by the Danish-English expeditions in the exploration of Greenland is not mentioned by the Dutch, neither the names which by them were bestowed on various localities. The nomenclature used by Hall in honour of Denmark and the Danish royal family quickly disappeared, whereas the Dutch names were retained.

The rivalry of the Dutch in the Davis Strait again aroused Christian IV's interest in the navigation of Greenland. When in 1636 a private company was founded in Copenhagen with this object in view, and with the burgomaster of the city at the head of the undertaking, he granted very extensive privileges, which will be mentioned in the chapter on the history of trade and colonisation in Greenland (Vol III).

On April 2nd, in the same year that this company had been founded, two ships were dispatched to Greenland, *viz.* "Røde Løve," commanded by Joris Carolus, and "Engel Gabriel," commanded by Willum Lauridsen. They went up into the Davis Strait, obtained some of the commodities of the country by trading with the natives, among other things a great number of narwhale tusks (Unicorn horns) and returned in August. Corfitz Ulfeldt, the then Lord Treasurer, is said to have reproved the skipper for returning so soon without investigating the country, and he pleaded in his defence that he had a great cargo of valuable gold-dust. However, the goldsmiths who examined it, declared it to be entirely valueless, whereupon Ulfeldt ordered the skipper to go out into the Sound with his vessel, which was still at anchor in the roads of Copenhagen, and throw the whole of the cargo

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[1] Isaac la Peyrère: Ausführliche Beschreibung des so-genannte Grönlands, durch S. von V. Nürnberg 1679 (German translation with explanations and additions to the French original) mentions, on p. 99, that the author in Bibliothèque Mazarin has found a map of Greenland executed by Arnolds de Briel 1624—25.

overboard without saying a word to anyone. If this account, which is due to Slange, is correct, the skipper in question must be Joris Carolus, as Willum Lauridsen as late as 1639—1643 took part in the voyage to the East Indies.

A new concession for the navigation of Greenland was granted to the trading company, founded in 1652 by Henrik Müller, Manager General of the Customs, in the privileges of which is mentioned "Greenland taken in an extended sense, the navigation of which country has for many years been unpractised and unknown."

For this purpose Müller equipped two vessels, and on May 8th they sailed for Greenland under the command of David Danell, a captain in the Danish Navy and a Dutchman by birth. He followed the same route as Allday, to the north of Iceland, and heading for the east coast of Greenland he sighted, on June 4th, the heights round Angmagssalik, but as the season was unfavourable for landing, he could not come near the land by 60 miles, for which reason he contented himself with taking bearings of the mountains, with exact determinations of latitude for the position of the vessels at the time of each bearing. A mountain situated in lat. 65° 30′ where the coast trends towards the west, and easily recognizable from afar, the Qalerajueq on Qulusuk, the southern extremity of which is Cape Dan, he called by the name of King Frederik's Cape. After having rounded the southern extremity of the country, he sighted Cape Desolation and Cape Comfort, and in lat. 63° N. came into touch with the Greenlanders; on June 25th he ran into South Isortoq and then into Itivdleq, where he anchored in Hall's Danmark's Harbour, which he called Müller's Harbour, and he also rechristened the Kangârssuk mountain (Queen Sophia's Cape) Cape Queen Amalia. In this place the crews found deserted Greenlander houses made of whale ribs and many graves. After having penetrated as far as lat. 67° N., Danell returned, passing Kin of Sale, which he called Fiskersbjerg. In Hamburger Sound (Tuno) Danell's crew traded with the Greenlanders, and from there, sailing by the map of Hall, he sought Ball's River, the position of which (Hjortetakken and Sadlen as well as the Kook Islands) he describes in detail. While sailing along the east coast Danell came quite close to the land at Iluileq (by G. Holm called Danell Fiord), attempted to land in lat. 61° 30′ N. and in lat. 63½° N., stood off towards Iceland and then for home.

On his second voyage in the following year (1653) Danell followed the same route, and in June he again sighted the bluish glaciers at Angmagssalik, but, as on the former occasion, without setting foot on the east coast. He once more ran into Ball's River and traded with the Greenlanders at Kangeq; then he went into Danmark's or Müller's Harbour, penetrated as far as Rifkol and returned. On his third voyage in 1654 Danell was only one mile from the east coast, but again he was prevented by the pack ice from going ashore.

This time he also entered Ball's River and by force carried away a Greenlander and three Greenland women (depicted in the well-known Bergen painting, now in the Ethnographical Museum at Copenhagen), and he further brought home a number of narwhale and walrus tusks. The results of Danell's voyages were mainly ethnographical. The natives were brought to the Court, which on account of the plague had been moved to Flensborg, and afterwards they were shown to Duke Frederik III at Gottorp and questioned by his librarian, the famous traveller Adam Olearius. With the assistance of a ship's surgeon, who had some knowledge of the Greenland language, he obtained some information about their habits and manner of living, and he also collected the first Greenland vocabulary, comprising about one hundred words, all of which he published in his "Moscovitische und Persianische Reisebeschreibung."

Other and fairly detailed information about the life and habits of the Greenlanders was brought home by a certain Nicolai Tunes, commander of a vessel sent out in 1656 by a trading company at Flushing for the purpose of finding new openings for the Greenland trade. He landed in a fiord in lat. 64° 10′ N. and navigated the coast as far as lat. 72° N. (South Upernivik) from which voyage dates a detailed description of the manner of living of the Greenlanders of those parts, which description was published in 1658, accompanied by interesting illustrations[1].

As an outward sign of the suzerainty over Greenland as part of the Danish-Norwegian crown, King Frederik III, probably in consequence of the voyages of Danell, incorporated its coat of arms — a polar bear (as a rule couchant, more rarely upright) in azure — with the stock-fish (Iceland) and the sheep (the Faroes) as is seen in the seal under Lex Regia.

In the same year Cort Adelaer, Niels Juel and Jens Rödsteen were granted a concession for the navigation of Greenland. The skipper chosen for this undertaking was Otto Axelsen, who is supposed to have been lost with his vessel on his second voyage in 1671, but further particulars are lacking. In the period 1673 to 1675 the enterprising merchant Jörgen Thormöhlen dispatched a ship to Greenland, the sailing master of which was Jan de Brouwers from Rotterdam, who is said to have made the voyage to Straat Davis as often as fifteen times, but the vessel was taken by a privateer, and the sailing master died underway[2].

At the beginning of the 18th century the Dutch navigation of Greenland began in good earnest. How thoroughly the Dutch were orientated as regards this country can be seen from the sailing directions prepared by Feykes Haan and published in 1720, as well as from his maps of Greenland printed at the same time, and which for the distance Sydbay (Holsteinsborgs Isortoq) to Disko contain such accurate indications of courses, distances,

[1] Louis de Poincy: Histoire Naturelle et Morale des Iles Antilles d'Amérique, Rotterdam 1658, 188 ff.

[2] Det Norske Geogr. Selsk. Aarbok 1919—21, p. 58.

harbours, rocks, skerries and shoals that a Greenland skipper to this day would be able to sail by them.

In former times, as P. O. Wallöe expresses himself in 1752, the Dutch on their whaling expeditions along the west coast made use of the harbours on the island Statenhuk (Putulik) in order to fetch fresh water, and a memento of their landing in the Julianehaab District is the so-called Hollænderø (Dutch Island) off Julianehaab. Dutch harbours from the olden times were the harbour used as an emergency harbour at Fiskenæsset and the above-mentioned Briel Harbour (Qilángait Bay) near the much dreaded rock, which by the Dutch was named Skinderhvalen (i. e. the carcass of a whale.)

Taught by ship-wrecks and other losses, the Dutch as a rule made a curve of up to 30 miles off the southern extremity of Greenland, heading past Witteblink, the ice-blink at Frederikshaab, for Dutch Harbour in Ball's River, with the object of trading with the natives. A dozen miles to the north of Godthaab, at the entrance to Fiskefiord, lay the above-mentioned, oldest known Dutch harbour: Delftsche Haven. Then follow: Old Sukkertoppen (Kangâmiut), by the Dutch named Suikerbrood (i. e. sugar loaf) an account of the shape of the rock, and they had their trading station at the neighbouring, well-peopled Narssamiut. The island Nipisat south of Holsteinsborg was before the time of Egede the South Greenland whaling station which was most frequented by the Dutch and Hamburg traders. Sydbay is the name bestowed by the Dutch on South Isortoq and the island in the same place (Ukîvik), where the skippers made appointments to meet when homeward bound.

Past North Strömfiord, which the Dutch called by the curious name Rommelpotten (from the childrens toy: "rommelpot"), off Wilde Eiland (Manîtsoq), past Rifkol (from *rif* = reef, and *kol* = knoll) or the dangerous Ũmánaq rock, they shaped their course in the direction of Disko (the origin of this name, which like several other Dutch names in Greenland has been taken from Spitzbergen, is uncertain, perhaps an abbreviation of Discord) off the islands Ivnalik, Ivnalínguaq, Akugdlît as well as Wester Eiland and Kol (Agpalilik) or, in a north-eastern direction, either past Qeqertarssuatsiaq into Nordbay (Nivâq Fiord) where they took a bearing of Boots-Klamp (i. e. boat-clamp), Mt. Nivâq, into Sydöst Bay or through one of the two sailing courses, Igíniarfik Sound and Oqaitsoq Channel, to Bonke-Eiland (Manîtsoq Island). The harbour bay of the whole of Egedesminde was called by the name Bonke- or Jessebay. North of Manîtsoq they went from Moortbay (at Akúnâq or to the west of it at Tasilik) past Aenebay, the most easterly corner of Nivâq Fiord in the neighbourhood of Nûk (Upernivik Islands) with Vlakke groene Eilanden (i. e. green islands) due north, into Sydost Bay, the northern part of which at the Nisa Land off the mouth of Kangersuneq was called Wildebay, recognizable by the tall and long

island Tugssâq. Between this and the Akugdlît Island the course was as far as Uigordleq, down into the eastern part of Sydost Bay, called Spiring Bay (from *spiring*, caplin). Past the flat island of Sârdleq they sailed in a northern direction to Wierebay (the harbour bay of Christianshaab) and Santbay, a great and wide bay capable of accommodating a whole fleet, then south of Claushavn up to Ysfiort, i. e. Jacobshavn Icefjord. Even the present Jacobshavn Bay (Kangerdluatsiaq) they called by the pleasant name Makelyk Oud (i. e. comfortable old age) which also occurs in the Spitzbergen map. The little bay at the settlement they called Kanal (i. e. channel); Bredebugt, situated one mile farther north is to this day called Hollænderbugten; Roobay (i. e. bay of rest), also called Rodebay, was frequented for its good and spacious harbour. On Arveprinsens Eiland (i. e. the island of the hereditary prince) lies Klokkerhuk (Klockhuk, the cleft hook) the latter, as contrasted with Flakkerhuk (Vlakkehoek), also being the name of the whole island. Zwartevogelbay (i. e. the bay of the black birds or auks) is partly the name of Langebugt (Kangerdluk) and partly the name of the present Ritenbenk.

Through the Vajgat the Dutch sailed across to Hasen Eiland (i. e. hare island), went fishing in Ũmánaq Fiord, which they called by the strange name Stikkende Jacobs Bay (perhaps derived from stikken, strangle) past Onbekande Eiland as far as the peninsula Zwartenhuk and from there to Vrouwen Eilanden (English Virgin Islands, Qaersorssuaq) which in all probability must be termed the most northerly point of the west coast which was known to the Dutch.

The Dutch also had three harbours on the south side of Disko Island: Fortuyn Bay (i. e. bay of fortune) and Liefde Bay (i. e. bay of love), Godhavns Harbour as well as Disko Reede with De Schans (i. e. the redoubt), recognizable by the mountain Iviangernat with its three hummocks, where they caught whales and fetched small coal, which is said to make a fairly good fire and to be able to burn a whole day. Midway between Godhavn and Egedesminde they touched Walvis Eilanden (in 1778 re-christened Kronprinsens Eilænder, i. e. the islands of the Crown Prince), the island group of which forms a comfortable harbour. South of these islands lies the skerry Rotten (the rock), by the Dutch called Rotgans Eiland after the bird Pelicanus bassanus.

The many names given above, some of which are used to this day, show the intimate knowledge of the localities of Greenland possessed by the Dutch.

There is no reason to doubt that the Dutch, as shown by the old maps, also investigated the north-west coast of Greenland from Spitzbergen. As early as 1607 Henry Hudson, on several occasions, sighted the land in lat. 73° N., and as a memento of his discovery we have the name Hold-with-hope inserted into later maps.

The Italian map of Coronelli (1690) shows a coast stretch in lat. 73° N. bearing the inscription that "Broer Ruys reached land in this locality." North of that lies Gaele Hamke's Coast, which is also indicated as having been found in 1654 and called after a Dutch whaler. Farther up, north of Lambert's Land which is laid down in the other maps, there is a note to the effect that the Dutch reached as far north as this in 1614.

In G. van Keulen's map from 1706 the year of discovery of Lambert's Land (in about lat. 78½° N.) is given as 1670, that of Land van Edam (in lat. 77° N.) as 1656, that of Bay van Gaele Hamke (in 74°) and of Land van Broer Ruys as 1654 and 1655 respectively.

That Gaele Hamke actually did exist appears from a German journal, which was published in 1639, and in which he is mentioned as the commander of the vessel "De Oranje-Boom," which in the same year was dispatched to Spitzbergen by the Greenland Company at Hoorn.[1]

In Denmark, Norway and Iceland the interest in the re-discovery of Greenland had been revived through the voyages of Danell, and several scholars were engaged in spreading the knowledge of the original Icelandic accounts of the old Norse settlements. As the west coast was thought to be fairly thoroughly investigated without any traces having been found of the old Icelanders, whose descendants were generally supposed to have survived somewhere in the country, attention was first directed towards the southern extremity and finally to the apparently unapproachable east coast.

Bishop Peder Hansen Resen (grandson of the foregoing Bishop H. P. Resen) in his summary of twelve voyages, compiled (1664) from "Grönlandske Chronica," was undoubtedly the first to set forth the view that the best manner of reaching the east coast was to secure a foothold on the west coast, and then to proceed round the southern extremity.

In the years 1668—1669 Bishop Thórdur Thorlacius prepared his great detailed map of Greenland in which, owing to erroneous conclusions, he was led to place on the south-western side the "Österbygd," whose centre, Eriksfiord, as late as in 1607 was referred to the southern extremity of Greenland, and to add two islands south of the country traversed by Frobisher Strait and Bear Sound. This erroneous conclusion was greatly helped by the fact that Danell had placed Herjulfnes in latitude 64° on the east coast.

The map of Thorlacius, which was first printed in 1706, came to exercise a decisive influence on the view of the position of the Österbygd as set forth by Egede and repeated in all maps of Greenland, until on his voyage to the east coast of Greenland it was definitely proved by Graah that the ancient settlement at any rate was not to be found south of lat. 65° N.

In 1683 the historiographer Thormod Torfæus applied to the King

[1] Journal van de ongelückige Voyagie, Gedaen by den Commandeur Dirck Albertsz, Raven Naer Groenlandt, 1639. Amsterdam.

with a proposal relating to the navigation of Greenland from Iceland by the shortest route between Bredefiord and Eriksfiord. According to this proposal vagrants from Iceland, Denmark and Norway should be sent up there as settlers; a citadel should be built towards the west and trading carried on between both countries. In 1685 he submitted a new project relating to the erection of a redoubt on the extreme point of the country at Cape Farewell, and with horses and boats from Iceland he proposed a thorough reconnoitring of the settlement towards the north, with a view to finding an opening through which a passage could be effected to the East Indies.

No less eager in his projects for the rediscovery of the old Greenland was the compatriot of Thorlacius, Arni Magnussen, the famous collector of MSS. From a letter written in 1704 to the President of the Treasury, Joachim Ahlefeldt, it appears that the King had decided to equip an expedition to Greenland, being in this matter influenced by Ahlefeldt, who was greatly interested in everything relating to Greenland and contemplated a German translation of the journals of Danell. For use in the preparations for this attempt, which was, however, never realized, Arni Magnussen compiled a summary of the Greenland voyages in the 17th century. The man whom Ahlefeldt "persuaded" to go to Greenland was Jacob Rasch from Stavanger. During the seven years which he spent in Copenhagen as private tutor to the children of Admiral Gedde, he had studied navigation and geometry, and as early as in 1700 he had submitted to the King a copy of the sailing directions collected by Erik Walkendorff. The "design entertained," as Rasch himself says, came to nought, and he accepted the post as head-master of a grammar school in Oslo. In the same year (1706) he published Torfæus' "Grönlandia antiqua," which he corrected throughout and provided with maps; in his opinion this work proved that Vinland, so called by the ancient Norseman, had been found by Leif, and he expressed the hope that it might be said of King Frederik IV, as it was said of King Haakon in 1260, that his dominion extended as far as the Pole. Other historical compilations relating to Greenland were undertaken by Matthias Heinrich Schacht (d. 1700), headmaster of a grammar school in Kjerteminde, and Andreas Bussæus (d. 1735), Burgomaster of Elsinore, who, *inter alia*, in 1732 published a Danish translation of Arngrim Jonsson's "Grönlandia antiqua."

The privileges granted by the King in 1697 to two Greenland companies in Denmark and Norway encouraged enterprising traders, in both countries, to make attempts at resuming navigation to Greenland. In 1699 the brewer and shipowner, Peter Klaumann, dispatched an expedition to the country, with his stepson, the later bank-commissary Gorris Klaumann, on board, but the vessel was wrecked, and the owner suffered great losses. In 1700 ten merchants of Bergen, who in the preceding year had equipped four vessels for the same purpose, petitioned for the exemption from taxes which

in the privileges had been promised to all who took part in the trade with Greenland. One of these petitioners was the enterprising Hans Mathias, who in 1708—being as he himself maintains the first person in Denmark and Norway who had done so within living memory—dispatched a vessel to Davis Strait, with the object of exploring the country, its trade and character, from which voyage his crew brought back a cargo of skins and blubber. In the years immediately following he continued the sailings to Greenland, but at last he had to give it up owing to lack of success. Besides him Major N. C. Bärenfels von Warnau and the later Alderman Magnus Schiötte, both residents of Bergen, sent vessels to Davis Strait in 1712—1714, the latter even as high up as lat. 80° N.

In the same year that Hans Mathias started the voyages to Greenland "for the benefit of his fellow citizens, that it should not be entirely in the hands of the Dutch," the Norwegian Hans Povelsen Egede (born in 1686 in Senjen in Nordland, and at that time rector of Vaagan near his native place) by reading P. Claussen's description of Greenland (1632) had conceived the idea of going up there in order to preach the gospel to the descendants of the old Norsemen. It must, however, be supposed that Egede's interest in this country and the missionary work to be undertaken in it had first been roused in Copenhagen, where he went for his studies, as it happened at the time (1704—05) when the plans for the Greenland voyage of J. Rasch were being discussed, and the first Danish missionaries were sent out to the Danish possessions in the East Indies. Through his brother-in-law, Niels Rasch, who had been a mate on one of the vessels of Hans Mathias, he obtained information of Greenland, to the effect that the country was inhabited by a savage people, and that the best place was in lat. 64° N. In the following two years he sent, first to the bishops of Bergen and Trondhjem and later on to the King, carefully made out reports on ways and means towards the conversion of the Greenlanders, without, however, obtaining any result from his application.

The great plague of 1711 and the northern war prevented him from repeating his petitions with any hope of having them granted. With his strong personality, however, he never for a period of ten years lost sight of the thought, until at last it had taken such a hold on him that he cut himself adrift and in 1718 went to live in Bergen, where he attempted to influence prominent merchants of the town in a resumption of sailings to Greenland. With the same object in view he, further, sent to the King a proposal for the establishment of a trading company in Bergen, and with the support of the Missionary Society he at last, in 1719, managed to interest the King so far in his undertaking that an order was issued to the magistrates of Bergen to summon the persons who under Hans Mathias and von Warnau had taken part in the voyages to Greenland. By the indefatigable labour of Egede a company was at last formed, consisting of enterprising and

public-spirited merchants of Bergen, who resolved to equip three vessels for Greenland. On May 12th, 1721, Hans Egede himself, with his devoted and courageous wife, Gertrud Rasch, and their four children, went on board one of the three vessels, the number of persons taking part in the journey amounting to forty all told. The skipper had orders to follow the sailing directions of Feykes Haan, and to attempt to touch land in lat. 64° 9′ N. After a stormy passage Hans Egede, on July 3rd, set foot on the soil of Greenland, and among the wildly jagged skerries of the coast he made his home on a small wind-swept island, not far from the place where in 1728 the Godthaab settlement was founded.

Strong man of hope that he was, he called it "Island of Hope", and here he spent the winter, the first European after the Middle Ages, who had voluntarily wintered in that region. To his perseverance and unbending will Denmark is indebted for the peaceful conquest of Greenland, while the natives are indebted to him for the preaching of faith, hope and charity. For fully fifteen years he held out courageously, facing all conceivable troubles and difficulties, and particularly during the great smallpox epidemic, which in 1733—34 scourged the country, he and his faithful wife showed their strength of soul in a self-sacrificing labour of mercy to which she at last fell a victim.

After his return to Denmark Egede engaged in literary pursuits, and by his versatile and instructive works on Greenland, the country and the people: "Omstændelig Relation" (1737) and "Det gamle Grönlands nye Perlustration" (1741), which latter has been translated into various languages and now ranks among the world-classics on primitive peoples, he spread the knowledge of Greenland throughout Europe. (Engl. "Description of Greenland, London" 1745).

The dual importance of Egede as a missionary and a colonizer will be dealt with separately in a subsequent chapter. Here mention is only to be made of his descriptions of hitherto unknown parts of the country which he visited and mapped to the best of his ability.

The many voyages undertaken by Egede in the Godthaab District during the fifteen years which he spent in Greenland, resulted in an intimate knowledge of these hitherto unexplored desolate tracts, which, ethnologically as well as historically, offer so many points of interest. He was the first who named the Ameralik Fiord and penetrated to its head, being also the first to see and describe the mysterious Norse ruin Ujaragssuit in Pisigsarfik Fiord, and time after time he visited the Raven Island, the Kook Islands and the labyrinths of the Pisugfik Islands.

In Bergen, where the almost legendary memory of the communication between Norway and Greenland had never been quite extinct, the work of Egede roused great enthusiasm, which partly expressed itself in pecuniary sacrifices, and partly in projects of re-discovering the Østerbygd by the route

followed by Erik the Red. J. Rasch, now head-master at Oslo, also entered the lists, and in 1722 sent to the Bergen Company all that he had received from the old Icelander, Thormod Torfæus, asking nothing for his labour but that a donation might be made to his school. Together with Resen Rasch proposed to circumnavigate the country by means of coasting vessels, which were to observe whether the entrances to the harbours were free of ice at certain seasons.

Under the heading of actual exploration comes Egede's expedition towards the south in 1723 when, as no one before him, he investigated the islands and the fiords, their trade-possibilities and memorials of the past, to about lat. 60° N. This journey he undertook first and foremost of his own accord, but also on the initiative of his Bergen partners, who had enjoined him, at midsummer and together with eight men, each provided with a knapsack containing provisions, a gun and compasses, to make an attempt at transversing the ice in the place where, according to the map, the country was narrowest — only 12 or 16 miles broad — with the object of finding the Österbygd.

For this purpose he equipped two small boats, and, accompanied by a pilot, he left Godthaab, passed Fiskernæs Fiord, which he called by its Greenland name, Qeqertarssuatsiaq, sailed on the outside of Frederikshaab Iceblink (the Sand Country) as far as Pâmiut (Frederikshaab). On August 16th he poled through the ice and across the mouth of Sermilik; then he turned round S. Kangeq into Tigssaluk Fiord, passed inside Tôrnârssuk through Isa Passage and farther, inside Ũmánaq and Stor Island, to Kitsigsut Islands, where he observed a change in the appearance and language of the people. On August 19th he reached Dutch Island, ran into Agdluitsoq Fiord, where he found copses and old Norse ruins, passed inside Sermersôq and penetrated as far as a mile to the north of Nanortalik (60° 5′). As he found no traces of a passage to the east coast, and the Greenlanders denied the existence of anything of that description, he resolved to turn back, particularly because provisions were very scarce, and his companions were afraid of the cannibals round Cape Farewell. The return journey was commenced on August 26th, and he followed the route inside the skerries to Qaqortoq, being the first European to see and describe the famous church ruin in that place. On his way back he passed Tunugdliarfik Fiord, which he named, and the iceblink inside Sermitsialik, which he connected with the glacier at Ujaragssuaq. He saw the Norse ruins at Ivigtût, passed on the outside of all the islands by Kvanefiord, with its ruins of houses, and reached his home on September 14th.

The course followed by Egede became a guide for subsequent voyages in a southern direction; he established that the people and the country described by Frobisher, like the strait called after him, cannot—as stated by Torfæus—have been part of the old Greenland, but beyond a doubt

must be looked for along the shores of America. As further results of this journey must be mentioned very valuable information about the manner of living of the natives whom he met underway, and in his account Egede expresses his great doubts as to the possibility of reaching the Österbygd overland.

On February 22nd, 1724, in the coldest season, Egede started on his second reconnoitring trip, again accompanied by a pilot as well as a harpooner and twenty men in two boats; in severe frost and ice the expedition, a week later, reached Kin of Sale, then went to the east of Manîtsoq through the Hamburger Sound, arrived on March 7th in the well-populated Narssamiut, and a week later reached Evighedsfiord (Kangerdlugssuatsiaq), where he penetrated as far as the glacier, but on March 16th constant strong gales from the north and snowy weather forced him to return.

This voyage, in the course of which Egede procured valuable information from the natives as regards the whaling to the north as far as Sydbay, gave rise to the establishment of a whaling station at Nipisat, where the Greenlanders caught the large whalebone-whales.

The old Norse ruins in which Egede, on this voyage as everywhere else, took a great interest and which he found on the whole of the distance lat. 60°—66° N., led him to the conclusion that he had traversed the "Vesterbygd" throughout its extent. His voyages in a southern direction strengthened him in the view already set forth in February, 1723, as to the destruction of the original settlements, whether, as substantiated by native traditions, the settlers had succumbed to privation and hunger, or they had been slain by the savages. That some of the old Norsemen might have mixed with the natives, he concluded from the Norwegian words which he thought he found in the Greenland language, and the natives did not gainsay him when he called them the "children of the Norwegians." On the other hand, he still believed in the existence of the Österbygd on the other side of Hukken, with a population of purely Norwegian extraction.

In April 1724 the Bergen Company sent out a hooker with the object of finding the east coast. Starting from Reykjanes it was to follow the old sailing directions, and the skipper had orders to reconnoitre all harbours and fiords, to find out the number of churches and cathedrals, where and in which fiords they had been situated, or at least to investigate their foundations; further, he was to give detailed information of the religion, manner of living and apparel of the natives, their foods and trades, as well as to try and find out whether they had a chief, while with the view of facilitating conversation the skipper had been given a list of the everyday words in the "Hirdskraa" (i. e. statutes for the King's men, written in the old Norse language). At the same time the company ordered another skipper, bound for the settlement of Egede, to head south from there through the so-called Frobisher Strait to the east coast, with a view to the possibility of a meeting

between the two vessels. The former vessel, for a period of three months, cruised off the coast from lat. 66½° to 60° 28′ N., and frequently came so close to the shore as only to be four—indeed on one occasion only one mile—removed from it, for which reason the skipper concluded that it was better to rest content with what had been begun on the western side of Greenland and from there to proceed to the east coast. The other vessel was last seen by a Dutchman 12 to 16 miles east of Cape Prince Christian, having probably been wrecked in the drift ice off the east coast or on its way back to the settlement.

When in the following year Egede learned of this result, he proposed to the company to make an attempt, either in the early spring when there was no ice, or in the late autumn when the ice had drifted away, to penetrate along the west coast, south of Hukken. The starting point of the expedition was to be a settlement which should be founded in lat. 61° N., and it was to be undertaken, not with one vessel, but by means of several sealing boats.

In the letter of instruction to Major Claus Enevold Paars, appointed Governor of Greenland in 1728, the latter was enjoined, immediately after the removal of the old settlement from Haabets Ø to the place chosen by Egede, *viz.* Nûk (Godthaab), to rediscover and reconnoitre the Österbygd by means of the horses which had been sent up with him, or by another route across land, with a view to ascertaining whether descendants of the old Norwegian settlers were still alive. At the same time Lieut. Jesper Reichardt, R.N., who was to go with the vessel, had received orders to make an attempt to reach the east side from Godthaab along the coast. In May Reichardt followed the course indicated and sighted land in lat. 63° 22′ N. Judging by the altitude he identified it with Warwick Point, and in lat. 64° 53′ N. he returned without seeing the least trace of the land, which was entirely blocked with ice.

Paars carried out his expedition in the following spring. On April 28th he left Godthaab, accompanied by an officer of one of the ships, the assistant of the trading station and five common sailors. With his party he penetrated for a distance of ten miles into Ameralik Fiord as far as Ameragdla, wandered about for two days with provisions and ammunition, together with two Greenlanders who lay in tents in this locality, and finally he reached a place called Univiarssuk. With ice-spurs and ice-spikes they all ascended the inland ice, the 2 to 3 fathom broad crevices of which seemed to Paars as "steep as the steepest church walls and as sharp-edged as sugar candy." They returned through the valley, which Fridtjof Nansen called the Austmanna Valley, when in 1890, after his ski-passage through Greenland, he descended from the edge of the inland ice.

On this occasion Egede set forth as his opinion that it would be utterly impossible to reconnoitre the "ice rampart" (the inland ice) over land, especially with horses, all Greenlanders who had ascended it declaring

it to be impossible, as it was full of deep crevices and clefts through which great rivers ran. Furthermore, the crevices were hidden under the snow, so that the Greenlanders who had pursued the reindeer for some distance in across the ice, had frequently fallen in and never returned.

If a settlement were founded between 60° and 61°, this would offer the best opportunity of finding the Østerbygd; "by land," he concludes, "I do not think, that it ever can be done."

When the news of Paars' failure reached home, a Norwegian, Matthis Jochimsen, in 1732, conceived the plan of making another attempt at crossing the inland ice. A long stay in Iceland had made him familiar with the difficulties awaiting him. Instead of horses, he wanted to catch and tame reindeer, with a view to transporting tents and provisions across the ice. He would try to find his way back by marking off cairns on the rocks and snow columns on the land ice. The expedition he requested was, besides himself, to comprise his brother, a servant, three young Norwegians of the foot-guards who, like his brother, were familiar with the taming of reindeer, and, further, two Icelandic students, who when returning to their native country would encourage their countrymen to move over to Greenland. In Copenhagen Jochimsen found a patron in the Secretary of War, Lövenörn, who effected a royal order for him and his brother and son to start for Greenland, but he was not permitted to take the Norwegian skiers nor the two Icelandic students. It is possible that this hardy man, accustomed to mountaineering, would otherwise have been able to carry out his project of crossing the inland ice on ski, as was at a much later period done by his countryman Fridtjof Nansen.

Jochimsen spent the winter in Godthaab, and on April 20th, 1733, he started south with two vessels and a crew consisting of ten men, all told. He reached lat. 61° N., passed outside Kangârssuk, which he called by the name of Langenæs, and penetrated for a distance of half a mile into the Sermiliarssuk, which was blocked with ice. Unlike Egede, Jochimsen believed in the passage through Frobisher Strait, and thought that it was only closed at this time of the year. Also in his case lack of provisions and difficulties arising out of ice conditions prevented him from continuing the journey, but, furthermore, his sailors were unwilling to do so, because they had heard from the Greenlanders that two vessels from Denmark had passed in a northerly direction with the object of fetching back all the Danes at the settlement.

The observations of Jochimsen from this journey mainly bear upon the variation of the compass and ice conditions. He imagined the ice to be shooting up above the mountains from the interior of the country, like a blue peasant's cap; in May, when the sun regained its strength, the lumps of ice were fluug down the precipice, or were carried out into the strait by the force of the rivers and the ebb. The

ice was collected between lat. 60° and 62° N., while the northerly current from Disko, which passed due south, further helped to bring about this result and to keep the masses drifting about the shore until the month of July, when the south-east wind blew at Hukken and the icebergs drifted towards the west. He established the subsidence of the water level throughout the years by means of marks in the rocks, and gathered information of the warm springs at Ũnartoq, which, however, he did not visit, any more than Egede did.

For a long time Egede had ardently wished for the establishment of a settlement in lat. 61° N. as a pioneering station for further exploration in a south-easterly direction, and this wish was fulfilled by the founding of Frederikshaab. The first merchant or trader was Lars Dalager, known on account of his "Grönlandske Relationer" (written in 1752 and published in 1758), which deal with the life of the Greenlanders, their habits and regulations, as well as their temperament and superstitions. This work is written in a racy, popular style and testifies to the bright intelligence and understanding of the author, with a sprinkling of the most delightful humour.

Frobisher Strait, which according to his opinion only lay seven miles to the south of his settlement, had long been a thorn in his side, when in the autumn of 1751 an account given by a Greenlander of a hunting excursion into the interior of the country, and his assertion that he had seen the mountains of the Österbygd induced Dalager to undertake a trip on to the Frederikshaab Iceblink. On September 2nd, accompanied by four Greenlanders and a native girl, he set off from the northern arm of Tiningnertôq Fiord (62° 30′) slightly to the south of the iceblink, passed first in a northerly direction by land to Taserssuaq Lake, and then in kayaks across the latter. During the following days the expedition undertook excursions on the ice, the smoothness of which, according to Dalager, surpassed that of the Copenhagen streets. His observations of the severe cold produced from the radiation of the inland ice, is the first known expression of its character. Dalager first ascended a nunataq, and then on the following day continued on his march towards the interior, where he ascended "the highest peak of the iceblink," which he called by the name of Omertlak, and which by J. A. D. Jensen was supposed to be identical with Nasaussaq Peak, ascended by him on his well-known ice journey in 1878, this supposition being, however, contested by Fridtjof Nansen. From here Dalager believed, like the Greenlander mentioned above, to be able to sight the "Kablunacic" (i. e. the Northmen's) mountains of the east coast, whereas in reality they were the nunataqs which by J. A. D. Jensen were named after Dalager in commemoration of his expedition. Apart from Paars, Dalager was thus the first European to set foot on the inland ice, and who has left a record of his journey.

Of Frobisher Strait Dalager says that "it seems practically thickened to eternal ice."

Dalager was very closely connected with the Moravian Brethren of Greenland and, in many respects, the principal source of their historian, David Crantz, who in 1765 published his detailed "Historie von Grönland," (translated into English: "History of Greenland," London, 1820) being the result of the knowledge gathered by him during his stay in Greenland. In spite of the severe criticism, written anonymously by H. C. Glahn ("Commentaries to the three First Books of Dav. Crantz's: Historie von Grönland, 1771"), this work is one of the most valuable sources as regards the culture of the Eskimos, as well as the history of the Greenland trade and mission. It further contains a geographical description of the country, with a number of interesting historical and topographical details, also from the east coast, which to a certain extent are due to Dalager. The people of Ũnartoq reported that in 1752 they had taken up two men from the east coast, who had made a journey as far as lat. 66° N., close in shore and extending over a period of three years, and they described the inhabitants of those parts as taller than those of the west coast, with the same language, but with a sing-song accent. The Eastlanders undertook the dangerous voyage past the ice current (Puissortoq) with the object of fetching iron and bone, which they lacked, from the Westlanders. They also told of a fiord from which, in the spring, cannibals issued, being supposed to be the descendants of the old Norsemen. On his map Crantz, in dotted lines, laid down a passage right across the land from Bear Sound, whereas Frobisher Fiord, which is imagined as being covered with ice throughout the country, is made to debouch on the east coast (Cape Frobisher). Along the east coast are placed the old Norse names from Eriksfiord to Øllumlengri, from where the outposts were supposed to begin.

The women's boat expedition from Godthaab in a southern direction, carried out with such admirable insight and endurance by P. O. Wallöe during the years 1750—1752, not only resulted in the first comparatively thorough investigation of the Julianehaab District, but even in the rediscovery of the east coast of Greenland, which had been a constant aim for so many years.

Peder Olsen Wallöe was probably the son of a Copenhagen skipper, and after serving his apprenticeship as a cooper he had, from 1737, been a sailor in the Greenland service. He lived as trade assistant at Christianshaab, from 1743 to 1748, when he was licensed to carry on trade on his own account at Godthaab, from where, in 1750, he undertook an expedition towards the south to Frederikshaab. From this expedition, as well as from his numerous earlier journeys along the coast, he left carefully worked out journals which testify to his great versatility and rare power of observation. On account of his familiarity with the Greenland language, the manner of

living of the natives and travelling in the country, the Mission College and the Greenland Trading Company entrusted him with the investigation of the south-west coast, as well as with making an attempt to discover the east coast.

At the beginning of August, 1751, he left Godthaab in a women's boat, accompanied by two sailors from the settlement and four female rowers, and a month later he reached Tunugdliarfik Fiord, the topography and Norse ruins of which he investigated and described. He took up his winter quarters at Igaliko Fiord, close to the place where Julianehaab was founded in 1775, and here he built a house which he called "first winter." The following spring he went into Agdluitsoq Fiord with the object of waiting for the Southlanders who assembled there for the caplin fishing. Together with more than four hundred natives he went to the fishing grounds, then he visited the warm springs at Ũnartoq and in midsummer, accompanied by two Eastlanders, he went by sea inside Sermersôq, passed Nanortalik and the neighbouring island, which he correctly describes as the place where Egede turned back in 1723. Although he was warned against shipwreck, starvation or the danger of being murdered by the ill-reputed Southlanders, he continued his voyage in regions where, as far as is known, no European had as yet set foot. With the impatience of the explorer, he hastened past Ikigait and Pamiagdluk, was—on account of the strong current—forced to abandon the thought of passing through Prince Christian Sound, and, after having touched the great island Igdlorssuatsiaq, east of Ilua, he rowed through Ikerasak and Ikeq Sounds, keeping Statenhuk Island on his right south-south-west towards the sea. Through the third sound, Ikerasik, he reached the outlet of Kipisarqo, and on July 6th he pitched his tent at the Eskimo camping site Ulimak on the east side, being the first Dane who ever did so. Here he remained for sixteen days, and here he found three families from whom he collected information of the appearance of the Eastlanders, their manner of clothing and living, as well as their language. As the only inhabited places on the east coast they named Avarqat, Umîvik, Naujánguit and Sermilik, all known from G. Holm's mapping of the Angmagssalik District. Farther north than Sermilik the natives never ventured for fear of the rapid current there. In the following week Wallöe and his followers suffered much from storms, cold and starvation, but in spite of that they slowly penetrated as far as Igalilik (Aluk) off the mouth of Prins Christian's Sound, went on past Kangerujuk (Cape Huitfeld) with its great masses of ice and Kangerdlugssuatsiaq Fiord (Lindenow Fiord) on the north side of which, on the southermost islands towards the sea, they pitched their tents at Naniseq, near the mountain called by the same name. From there Walløe saw the ice lying solid for miles off a promontory in an easterly direction, which Graah called Cape Wallöe (Kangeq) after him. But as the natives and the Danes who accompanied him refused to

go on, he was obliged to turn back from this place (on August 8th). The expedition returned through Prince Christian's Sound, wintered at Qagdlumiut in Agdluitsoq Fiord, and during the latter part of February, 1753, reached Frederikshaab, from where Wallöe returned to Denmark.

That the ways and means employed by Wallöe for the investigation of the east coast were the right ones, was proved by the women's boat expeditions of Graah and Holm. In 1886, exactly one hundred years after Wallöe, then an old man, had finished a carefully elaborated project for further penetration, G. Holm raised the Danish colours at Angmagssalik.

Thirty years after Wallöe's voyage, the Trading Company entrusted to Anders Olsen, the highly esteemed founder of Fiskenæsset, Old Sukkertoppen (Kangâmiut) and Julianehaab, as well as the first farmer and owner of real estate in Greenland, to travel from his own place, Igaliko, "from bay to bay, from fiord to fiord as far as Statenhuk and on to the east side." Everywhere he was to be on the look-out for possibilities of fishing and habitation and also for the rudera of the old Norsemen.

In July, 1783, at the age of sixty-four, Anders Olsen started on this journey together with his son, and according to his brief report he reached 18 miles to the north and north-east of Statenhuk on the east side. However, drift ice and winter ice, which lay solid along the shore, prevented further penetration. The Greenlanders he met, told him that the ice would drift loose in August, but as this meant that he would be unable to reach home before the coming of winter, he turned back.

Of voyages of exploration in the Julianehaab District should be mentioned those undertaken in the years 1777 to 1779 by the merchant A. Bruun, Julianehaab, together with his assistant Aron Arctander, with the special object of finding places fit for raising cattle. They visited the old Norse settlements with the rich pasture land, the ruins being described in detail by Arctander, among others many which have since disappeared or been disturbed, and many which of recent years have been re-discovered by G. Holm and D. Bruun. The diary of Arctander was printed in the weekly periodical "Samleren" VI (1792) and edited by H. P. von Eggers, who here found "the detailed description of a more recent date," which he lacked, when through other channels he had become persuaded that the Österbygd was situated in the Julianehaab District, and so he was now able to insert the old names into Arctander's map. A. Bruun's diary from 1777 to 1778, which is preserved in MS., helps to substantiate the notes of Arctander; besides it is more personal in character and contains matter of special interest, in that the writer tells of his meeting with the survivors of the great wreck of the Dutch and Hamburger whalers off the east coast of Greenland. This whaling fleet, which operated in lat. 78° 80′ N. (Lambert's Land), had at the end of June, 1777, been jammed in the ice and set adrift in a southerly direction. Many of the vessels succeeded in getting free of the ice, but twelve

of them were carried down into the dangerous waters of Danmark's Strait, sighted Gael Hamke's Land, but were subsequently all wrecked, some of them in lat. 61° 30′ N. The crews, after the loss of their vessels, attempted to reach land in sloops, but drifted past Hukken and up along the west coast, where they were taken ashore in a very pitiable state, some near Narssalik, from where they were carried as far as Frederikshaab, while others managed to reach Arsuk and were taken ashore at Julianehaab. In lat. 63° N. some are said to have reached an island on the east coast, from where they returned to the vessel, being unable to reach the main land. Others undoubtedly landed on the east coast, where they died.

Of the very sparse material regarding North Greenland during the 18th century should be mentioned that Volquard Bohn (a native of Boldixum on Föhr, off the west coast of Slesvig, who died as alderman in his native island) on a whaling expedition in the days June 21st—July 30th passed the east coast of Greenland from lat. 76° to 68° 40′ N. at a distance of 1½—6 miles. On the map executed by him from this voyage, it is indicated that in lat. 70° 40′ N. he was driven in a strong gale into a large fiord, the width of which he estimated at no less than 15 miles and extending north-west by west. As even in clear weather it was impossible from the topgallant yard to see the head of this fiord, and as the current continued to set inwards, Bohn concluded that the fiord passed right through the country, and so should rather be termed a strait. There is no doubt that Bohn has been in the sound, which was found in 1822 by William Scoresby the younger, and named after his father.

The hope of the re-discovery of the Österbygd was kept alive, particularly by Povl Egede, who in his interesting work "Efterretninger om Grønland" (1788) declares that the Österbygd has been his constant thought for fifty years. He remarks bitterly that his father, after his return from Greenland, declared himself ready to make the attempt, but that he never got any answer.

In his efforts to rouse the interest of the Government in the equipment of such an expedition, Povl Egede was supported by the Icelander Jon Erichsen, an authority on the literary remains of his native island, who in 1787 published Christian Lund's extract of the last travelling journals of Danell.

The Iceland Commission appointed in 1770 had also, as part of its programme, the discussion of the possibility of re-discovering the Österbygd; and to this commission J. Erichsen addressed a report, which was repeated and further elaborated in 1778. Of the three roads which might be imagined as leading to the goal: 1) to go across the country, 2) to follow the coast round Statenhuk, 3) from Iceland to steer across to the east coast,—he considered the first impracticable, the second, considering the experience gathered by H. Egede and P. O. Wallöe, not quite impossible with the

continued laying out of stations south of the Julianehaab settlement, which had been started in 1775, but as this would be very slow work, and he feared the dangerous route past Frobisher Strait on the east coast, he preferred the third plan. Iceland was nearest to Greenland, and from there the attempt might be made in accordance with the old sailing directions. From Snäfelljökull the course ought to be shaped due west for twenty-four hours, then south-east in order to avoid the ice at the Gunnbjörn Skerry, and, finally, north-west. For the expedition should be used two of the vessels of the Greenland Trading Company, a hooker and a three-masted galliot. On each of the vessels there should be an Icelandic student, so as to be able to converse with the old inhabitants, in case such were to be found.

About the same time Frederik Christian de la Roche Gallichon, who had held a high official position in Holsteen, set forth a proposal for an expedition with the object of re-discovering the Österbygd, maintaining that the country traversed by Egede, in spite of the rudera demonstrated there, could not be identical with the Greenland which had been visited at the latest during the reign of Queen Margrethe, and which had first been discovered by the old Norsemen. Though a mere windbag who wanted to reach his goal by the north-west passage, he nevertheless succeeded in having a commission appointed for the testing of his project, which commission consisted of three of the most eminent men of the country. Ten years later, when he once more set forth his project, he was, however, dismissed.

In 1785 Povl Egede succeeded in interesting the young Crown-Prince-Regent, who took a lively concern in everything pertaining to the vital interests of his subjects, and out of the fund *ad usus publicos* he granted 12,000 Rigsdaler towards an "attempt at discovering the east coast of Greenland."

As the leader of the expedition which was to be sent out during the following spring, was appointed Captain Poul Lövenörn, of the Danish Royal Navy, while two ships were equipped for the purpose, a whaler and a yacht. According to the plan, the larger vessel was to return in the course of the same year, whereas the smaller, if the object of the expedition was not attained during the first summer, was to spend the following winter there and then renew the attempt. On June 27th both vessels left Reykjanes, and on July 3rd Lövenörn sighted the country round Angmagssalik, between lat. 65° and 66° N., but on account of the masses of drift ice he resolved to go back to Iceland. He again left for Greenland on July 23rd, but meeting the drift ice already on the following day, he gave up the attempt. At the same time that he returned to Copenhagen, the yacht which had been stationed at Reykjanes, under the command of Christian Thestrup Egede, the son af Povl Egede, and C. A. Rothe, both lieutenants of the Royal Navy, headed north towards Greenland. Egede sighted land in lat. 65° 24′ N., took bearings and drew land sights over a distance of twenty miles,

and then sailed along the country without discovering any opening through which he might penetrate to the coast. In lat. 64° 50′ N., 2½ miles off, he took the bearings of a deep and broad fiord filled with icebergs. Strong and continuous storms from the east forced him to try to return to Iceland, where he spent the winter.

In the following year he made renewed attempts, first at the beginning of March and then three times in the course of the summer, but ice and fogs with gales and storms again and again frustrated his efforts.

Before the end of the century all of the existing settlements had been founded along the west coast from lat. 72° to 60° N., *viz:* Christianshaab (lat. 68° 49′ N.) 1734; Jacobshavn (lat. 69° 13′ N.) 1741; Frederikshaab (lat. 61° 59′ N.) 1742; Ritenbenk (lat. 69° 45′ N.) 1755; Holsteinsborg (lat. 66° 55′ N.) 1760; Sukkertoppen (lat. 65° 24′ N.) 1761; Egedesminde (lat. 68° 42′ N.) 1763; Ũmánaq (lat. 70° 40′ N.) 1763; Upernivik (lat. 72° 47′ N.) 1772; Julianehaab (lat. 60° 42′ N.) 1775.

With the support of the Danish Government the mineralogist Karl Ludwig Giesecke, within the period 1806 to 1813, traversed the whole of the colonized coast, with the object of collecting minerals and gathering information as to the economic condition of the country. Giesecke was born at Augsburg (1761); in his youth he was an actor and a dramatic author (he wrote, *inter alia*, the text of the "Magic Flute") and then turned to mineralogy. Already a mining expert of repute he embarked for Greenland in the summer of 1806, on a visit which was intended to last for two years and a half, but which, owing to the war between Denmark and England, came to cover a period of seven and a half years. During the first summer he traversed the Julianehaab District in an umiaq, passed through Prince Christian Sound to the east coast at Aluk (lat. 60° 09′ N.), the previously mentioned camping site of P. O. Wallöe, but he did not penetrate so far north as the latter. During the following summer (1807) he travelled through North Greenland to Upernivik, reaching Nûluk (lat. 73° 50′ N.), which is one degree farther north that the settlement, and where virtually no Danes had been before his time. He was accustomed to this kind of travelling from a former visit to the Faroes and, further helped by his perseverance and frugality and his rare ability of getting along with the native population, he moved about incessantly "hewing and cleaving stones from morning till nightfall." His mineralogical and ethnographical collections were sent home during that year, but the vessel was captured by the English, and the collections were seized and sold at Edinburgh. However, they were subsequently acknowledged to have been made by him, and he reaped the full glory among mineralogists of having found hitherto unknown minerals. In 1808 he traversed North Greenland and the Godthaab District, the latter also in the following year together with the Frederikshaab and Julianehaab Districts where, at Arsuk, he identified the occurrence of cryolite. In 1810

he travelled along the coast from Godthaab as far as Godhavn. In the following year he revisited the same region and also Ritenbenk and Ũmánaq, and in 1812—1813 he visited Disko Bay with Egedesminde and Christianshaab.

Giesecke's observations in the country were written down in a diary, comprising in all twelve hundred quarto pages. This diary was first published by F. Johnstrup in 1878, subsequently in 1910 (unabridged) by K. J. V. Steenstrup and, apart from its importance as a source of information on the history of mineralogy, it is the only detailed travel book comprising the whole of Greenland.

It contains a wealth of information on numerous remote places formerly visited by the Greenlanders, but now deserted and otherwise forgotten even to their very names, and of extremely valuable linguistic, zoological and botanical facts, which will for ever make it a work to be consulted by conscientious travellers in Greenland. Besides, Giesecke brought home very large mineralogical and ethnographical collections, which he distributed over the whole of Europe, the most valuable being acquired by the Imperial Collection at Vienna. He died, greatly honoured, as Professor of Mineralogy and Keeper of the Museum at Dublin.

SCIENTIFIC INVESTIGATIONS IN GREENLAND

BY

C. F. WANDEL,

Vice-Admiral.

The intimate knowledge of Greenland possessed at the present day—which knowledge is greater than that of any other Arctic country—is mainly due to the expeditions and investigations undertaken under the auspices of the Commission for the Direction of the Geological and Geographical Investigation in Greenland. This commission was appointed in 1877, but before entering into details as to its activities mention must be made of what has been done by way of independent scientific work by Danish or foreign explorers, prior to, or simultaneously with the work carried on by the Commission.

Until the early years of the 19th century there is no question of scientific research on a large scale, our knowledge of Greenland until that period being in the main limited to the following publications: Hans Egede: "Det gamle Grønlands nye Perlustration eller Naturel-Historie" (Copenhagen 1741), which work for its time must be said to have achieved a very high degree of excellence; David Cranz: "Historie von Grönland." (Copenhagen 1765); the valuable zoological works of the clergyman and missionary Otto Fabricius (Medd. o. G. LXII) and Peder Olsen Walløe's "Rejsebeskrivelse" (Samleren vol. I. Copenhagen 1787 cf. a later Edition by L. Bobé, Copenhagen 1927).

In 1806 the German mineralogist K. L. Giesecke, assisted by the Royal Greenland Trading Company, undertook a voyage to Greenland with a view to examine its minerals, Greenland in this respect being a perfect *terra incognita*. Giesecke's stay came to extend over a period of seven years and a half, which was partly due to the temporary interruption of the intercourse with Denmark caused by the war with England, in consequence of which he had to undergo great sufferings and privations.

However, in the course of his long stay, Giesecke succeeded in making a thorough investigation of the whole of the west coast from Upernivik round Cape Farewell to the island Aluk in lat. 60° 02′ N., and the results of his able work are partly to be found in his diary which was submitted

to the Royal Greenland Trading Company, and partly in his great mineralogical collections, the chief part of which was taken to Copenhagen. The contents of this diary, with a biography of Giesecke and a complete list of his writings, are to be found in Medd. o. G. XXXV.

After the publication of "Mineralogica Greenlandica" by Professor O. B. Bøggild (Medd. o. G. XXXIII) Giesecke's diary has become of less importance than formerly, when it was the sole book of reference regarding the minerals of Greenland; still, it will always be of great value to anyone who wants to study the development of our knowledge of the minerals of this country.

The American War of Independence and the Napoleonic wars had, for a period of about forty years, put a stop to Polar exploration on the part of England, but after the fall of Napoleon it was once more taken up with the old object of finding the north-western passage. However, immediately after the conclusion of peace, English and American whalers had carried on whaling in Davis Strait and Baffin Bay, all the way up to Cape York, thus contributing towards the knowledge of the waters of Greenland.

In 1818 the English Government sent out the vessel "Isabella"with Capt. John Ross in command, and another vessel, the "Alexander," commanded by Lieut. W. E. Parry, under the supreme command of Capt. Ross, the object of the expedition being to find the north-west passage.

The vessels left Lerwick on May 2nd, reached Davis Strait on May 23rd, began to have difficulties with the ice in lat. 65° N., and on June 9th were forced by impassable ice masses to anchor at an iceberg in lat. 68° 22′ N., where they were visited by the natives. In their neighbourhood were also several whalers, from whom they received less favourable information of ice conditions in the north. On June 14th they were off Whale Island (Kronprinsens Ø) the trading manager or governor of which came on board and said that the preceding winter was the hardest he had experienced for eleven years, and that in his opinion the chances of penetrating into Baffin Bay were very small.

The vessels worked their way towards the north, as far as Hare Island. Here they fell in with a number of whaling vessels, beset by the ice, and the crews of these together with the members of the expedition helped each other to got the ships farther north, where conditions were better. In lat. 70° 54′ N. the "Isabella" was visited by natives, the Eskimo John Sacheuse, who had been taken along from England, having first been ashore among them. Partly sailing, partly warping and towing they passed Devil's Thumb on July 18th. During this slow penetration towards the north land was sighted at the forelands Horse Head and Red Head, the large bay between lat. 75° 12′ and 76° N. being named Melville Bay, the curious rock in the middle of the bay, Melville's Monument, and the western extremity of the bay, Cape Melville; a bay to the west of the latter was named Regent Bay,

and the western foreland where the coast trended north-west, Cape York. In lat. 75° 22′ N. and long 64° 43 W. the "Isabella" was beset by the ice and was lifted several feet; when the pressure ceased, she drifted towards Cape Alexander, both vessels getting off without serious damage.

From the land inside Regent Bay, which was named the Arctic Highlands, the "Isabella" was repeatedly visited by natives. In his report Ross gives a very interesting description of these people, as well as of the appearance of the country and its productions, with which he had become acquainted by visits on shore.

From Cape York the vessels, with tolerable ice conditions, headed north along the coast. To the surprise of all on board the latter was of a red colour, which caused a boat to be sent ashore in order to find the explanation of the phenomenon, and it proved that the red colour was of vegetable origin, probably due to plants covering the mountains situated behind the coast.

Cape Dudly Didge was passed, and on August 18th the ships were off Wolstenholme Sound. A curious rock was named Dalrymple Rock, the southern promontory at the entrance of the sound Cape Athol, and the northern point Cape Stair. The wind being favourable the vessels, on the same day, came abreast of Whale Sound; the two promontories at the entrance of the sound were named after Lieutenants Parry and Robertson, while a small fiord south of Cape Parry was called Booth Sound. In the evening the Carey Islands were sighted, and on the following morning they were passed. In spite of considerable ice obstacles Hackluit Island was passed, and on the 20th the ships were off a large promontory, the country north of Whale Sound, which was named Cape Saumarez, the vessels at that time being in lat. 76° 54′ N. On the preceding day Ross thought that he sighted the entrance to Smith Sound, and the promontories on both sides were named Cape Isabella and Cape Alexander respectively, from which a distance of 86 km was reckoned.

All attempts at reaching the head of Baffin Bay were frustrated by impassable ice masses; in the course of these attempts two tall promontories were sighted on the western side of the head of the fiord, which were Cape Hurd and Cape Mouat, and all the time continuous land was sighted, in front of which there were huge icebergs.

On August 21st Ross abandoned the hope of penetrating farther north, and he writes in his report: "From these several considerations it appears perfectly certain that land is here continuous, and that there is no opening at the northernmost part of Baffin Bay from Hackluit Island to Cape Clarence. Even if it may be imagined that some narrow street may exist between these mountains, it is evident that it must for ever be unnavigable and that there is not even a chance of ascertaining its existence, since all approach to the heads of these bays is prevented by the ice, which fills them to so great a depth and appears never to have moved from its stations."

After this Ross followed the western side of Baffin Bay in a southern direction and returned home.

The result of this part of the expedition is a description of the west coast with names of easily recognizable points, a number of soundings, determinations of inclination and declination undertaken from the ice or small islands along the shore, and, finally, a valuable description of the psychology of the primitive "Arctic Highlanders," their habits, mode of life, clothes, weapons and the like. The highest latitude attained was 76° 54′ N.

In 1822 the Scottish whaler William Scoresby succeeded in mapping the east coast of Greenland from lat. 69° to 75′ N., first by surveys, carried out from the sea, and subsequently, after having landed at Cape Lister in lat. 70° 30′ N. lat., by surveys from and along the shore from lat. 69° 13′ to 72° 12′ N.; he visited Scoresby Sound, Hall Inlet, Hurry Inlet, Jameson Land, Cape Brewster, Cape Stewart, etc. Scoresby was the first European to set foot on that part of the shore; he was a well-informed man, and in the accounts of his travels there was a good deal of valuable information on the geology, zoology, botany and magnetism of Greenland ("Journal of a Voyage to the Northern Whalefishery," Edinburgh 1823).

In 1823 the English Government sent out the brig "Griper," under the command of Capt. Clavering, to the northern part of Norway, Spitzbergen and North-east Greenland, where Capt. Sabine was to carry out pendulum observations.

On August 13th Sabine went ashore on the east coast of Greenland in about lat. 74½° N. on an island, which was subsequently named after him. While Sabine carried on his investigations, Clavering explored the surrounding country, and during a few days' stay on an island (lat. 74° N.), which was likewise named after him, he found a tent inhabited by twelve Eskimos, this being the only case in which Eskimos have been found on the east coast of Greenland north of lat. 66° N.

In 1828 the Danish Government sent out an expedition under Lieut. Graah of the Royal Navy, with a view to investigating the east coast of Greenland from Cape Farewell in a northerly direction, thus settling the still prevailing dispute as to the situation of the old "Österbygd," the earliest Scandinavian settlement of Greenland. Lieut. Graah, who had already done valuable survey work in Greenland was accompanied by the botanist Vahl and spent his first winter, 1828—29, at Nanortalik, there occupying himself in surveying the regions adjoining the coast.

In the spring of 1829 Graah started from Nanortalik, and after great hardship reached lat. 61° 47′ N. on the east coast. Scarcity of provisions forced him to send back half of the members of the expedition under Vahl, while he himself continued in a northerly direction, as far as lat. 65° 12′ N., which he reached on August 18th. In the name of King Frederik VI he took possession of the country, but owing to the lateness of the season he

determined to abandon the attempt of penetrating farther north and went south to Nukarbik, an Eskimo dwelling place in lat. 63° 22′ N., where he wintered.

In the following autumn Graah was back at Friedericksthal, very exhausted from the winter spent in the Eskimo dwelling place, and in particular from the sufferings undergone during the return journey, especially from lack of provisions. The winter 1830—31 Graah spent at Julianehaab, and after recovering his strength he continued the surveying work begun in 1829, and eventually returned to Copenhagen, where he arrived on September 13th, 1831.

The results of this journey consisted in the surveys made, magnetical observations and the collection of ethnographical, zoological and botanical specimens, but of the old eastern settlement no traces were found.

Vahl remained in Greenland until 1836, carrying on his botanical researches, and in 1838 the coal strata of Disko and Hare Islands were examined by the zoologist J. C. Schytte.

Among the names indelibly written in the annals of Greenland is that of H. J. Rink, no less from the point of view of administration than because of his extremely valuable research work. After having joined the corvette "Galathea" on its voyage around the world, he spent, with the support of the Danish Government, the years 1848—51 in the northern part of Greenland, in order to carry on geological and mineralogical investigations. The greatest result of this journey was, however, his observations of the natural conditions of Greenland, in particular of the inland ice and the ice fiords with their icebergs. These observations, which were made known to the public in his work "Om Isens Udbredning og Bevægelse over Nord-Grønlands Fastland samt om Isfjeldenes Oprindelse" (Tidsskrift popul. Fremstilling Naturv., Kbhvn. 1855) aroused the liveliest interest in these problems throughout the whole of the scientific world. After a journey to South Greenland he was, in 1853, made "Kolonibestyrer" (superintendent) at the Julianehaab District and later at the Godthaab District; from 1858—68 he was inspector of South Greenland and then returned to Copenhagen. In 1857 he finished his classical work, the result of many years spent in Greenland, the title being "Grønland geografisk og statistisk beskrevet" (2 vols). In an extended form this work was later on published in English under the title "Danish Greenland, its People and Products," and it was followed by treatises dealing with various aspects of Greenland (Medd. o. G. XIII).

In 1852 the small two-masted schooner "Isabel" was equipped with provisions for twelve men for a period of five years, the purpose of the expedition being to pass through Bering Strait and to search the arctic waters north of America for the vessels of the Franklin Expedition. The expedition was, however, abandoned, and Lady Franklin who had defrayed

the costs of vessel and provisions, offered it with its cargo to Capt. Inglefield, who was to defray all expenses of an expedition, the ultimate aim of which was the delivery of the said cargo to the English ships stationed in Lancaster Sound. Capt. Inglefield accepted the offer, in the hope of making interesting discoveries in Baffin Bay, on his way to Lancaster Sound.

With a crew of 17 men, including a mate, a physician, an engineer and two ice-masters, Capt. Inglefield in the "Isabel" left the Thames on July 4th, 1852.

After a good deal of difficulty with the ice Inglefield, on August 7th, reached Fiskernæs, which he left after a day's stay, and without attaining his purpose, *viz.* to get dogs for the subsequent expedition. On August 12th he called at Disko, but here again his intention of getting dogs was frustrated, as Sir Edmund Belcher, a short time previously, had secured the entire stock of the settlement.

After further considerable difficulties with the ice Inglefield, on August 15th, arrived in Upernivik, where he secured dogs. After a severe gale on the 17th, which caused a good deal of damage, he passed Melville Bay on the 19th, but his progress was for some time stopped by ice off Pituvfik Glacier, where he was in communication with the natives, and he made use of his enforced stay to survey the coast; later on he went ashore at N. Ũmánaq where he did not meet the natives, but visited their huts, an easily recognizable rock north of this place being named Mount Dundas. On the 23rd he passed through Wolstenholme Sound, and on the following day he sighted the curious rock, Fitzclarence, which makes an excellent landfall for Booth Sound. He attempted twice in a storm to reach Granville Bay, but as the weather became calm, he finally gave it up and headed for Cape Parry; Carey Islands were passed at a distance of 8 km, and 32 km north of Cape Parry he was ashore among the natives, whose huts he examined carefully with the purpose of finding European objects, but without any result. The journey was continued under rather fair conditions; the two islands north of Whale Sound were named Northumberland and Herbert Islands; the sound between the latter was navigated, and the islands situated to the north of it were named Milne Islands, whereas the broad sound to the north of all of these islands was named Murchison Sound.

Inglefield felt rather tempted to investigate the coast stretch north of this locality, but conditions being favourable he gave it up and headed north. On the 26th he was ahead of Cape Alexander, and Smith Sound appeared open and comparatively free of ice. The small island south of Cape Alexander was called Sutherland Island, the rocks to the north were called Crystal Palace Cliffs, and a projecting promontory far out on the west side of the sound was given the name of Cape Albert. During the northern course of the vessel, much survey work was started, but it was stopped by a gale from the north, and Inglefield headed for the western coast of the

strait to see whether there should be any cairns, but he was stopped by a 12 mile broad belt of coast ice. In the course of the survey undertaken the following names were given: Cape Victoria to the farthest promontory on the west side, and Capes Camperdown, Sabine, Cracroft and Wade to other promontories farther south. On the east side the extreme point was named Cape Frederik VII and the bay to the south of the latter Lady Franklin Bay, while the island north of Crystal Palace Cliffs was called Littleton Island. As it proved impossible to reach the western coast, the expedition headed east, the width of the sound in this place being determined at 58 km. A gale from the north, which carried great ice masses with it, prevented further penetration beyond the latitude reached, *viz.* 78° 28′ 21″.

On the 28th the gale increased, and on the 29th the "Isabel" was exposed to great pressure between the floes of ice, which were set into violent motion by a heavy ground swell. Inglefield himself considers it a perfect miracle that the ship was not wrecked, but got out of the ice. Subsequently the western coast was followed in a southern direction, and Lancaster Sound was reached on September 7th.

Six hundred miles of hitherto unsurveyed coast had been charted, mistakes corrected and Smith Sound outlined.

In 1853 the brig "Advance" was equipped by several American scientific institutions, for the purpose of penetrating, from the most northerly point in Baffin Bay, in the direction of the North Pole, and to search the coast for traces of the Franklin Expedition.

The "Advance" registered 170 tons, and besides the leader, Dr. Kane, the expedition, consisted of 17 members, *viz.* Henry Brooks, first officer, the physician Isaac Hayes, the astronomer August Sontag and a crew of fourteen men.

Kane left New York on May 30th, 1853, took fifty dogs on board in Newfoundland, shaped his course for Fiskernæs on Greenland, where the Eskimo Hans Christian joined the expedition and left the settlement on July 19th. Then the vessel called at Sukkertoppen, Upernivik and Prøven, and on July 28th it reached the southern part of Melville Bay, where it met with serious ice obstacles; then again found open water, and on August 5th was off Crimson Cliffs, the red colour of which was observed, passed Wolstenholme and Saunders Islands on the same day and, on the following, Hackluyt Island. On August 6th the headlands at the entrance to Smith Sound were sighted from afar; on the 7th Kane was off Littleton Island and here laid down a depot consisting of provisions, clothes and the life boat of the vessel; this being done, he raised a cairn and then headed north.

From now until the 29th the progress of the "Advance" was a constant struggle against the ice; on several occasions it was lifted so as to lie on one

side; the rudder was damaged, and so everything that was loose was lashed and as much as possible brought on deck, in case it should prove necessary to leave the ship at a moment's notice. The "Advance" had all the time kept close to the shore, seeking the shelter of small bays or of rocks and islands, and on the date mentioned above it found itself in a bay which was named Rensselaer Harbour. A ship's council was held, and in spite of the opinions expressed by the latter, Kane decided to seek a harbour farther south in order to find a winter station from where the sledge journey might begin in the spring.

In August 29th, when the "Advance" lay at anchor in the small bay, Kane left the vessel, accompanied by Brooks and six men, with a boat equipped with provisions and instruments. The command of the ship was entrusted to the sailor Ohlson, who was of Danish parentage.

After twenty-four hours of strenuous marching, the sledge party ascended the coast, where the boat was left behind, and the journey was continued in sledges, along an icefloe, which towards the east was bounded by steep and high cliffs. After five days' marching and a delay caused by the passing of a broad glacier, observations showed they had only reached a distance of 64 km from the shore, and so they left the sledge, only taking the instruments with them and each man carrying his provision of pemmican. On the fifth day they were stopped by a large fiord, which was crossed by wading through a broad river, running out into the fiord; a few kilometres farther off the latitude was found to be 78° 52′ N. Here Kane left four men and the theodolite and went on with the others, only carrying a telescope and a sextant, as well as pemmican for three days. After a walk of 19 km they reached an altitude of 300 m and a headland which was named Cape William Makepiece Thackery. Here bearings were taken to known points, and the wide outlook showed that there was no better harbour than the one where the "Advance" lay.

After the return of the sledge party everything was made ready for wintering. The vessel was moved to the safest place in the bay; a house was built for provisions on Butler Island, and a kennel on the shore; astronomical, magnetical and meteorological observatories were constructed; the vessel itself was covered over, while sledge-driving was practised, and preparations were made for the laying out of depots. On September 20th, the second officer McGary and six men went in a northern direction along the coast; after five days' journey they laid out the first depots, one at Cape Russel, another 30 miles farther on and the third on October 10th on a small island named after McGary, the latitude of which as determined by dead reckoning was 79° 50′. From this island the large glacier was sighted, which was subsequently named Humboldt Glacier. The absence of the sun prevented them from making astronomical observations, but with their sextant they took bearings to several easily identifiable points.

The following months were passed in the hunting of walrus and foxes; a long sledge trip was made with a negative result to some formerly observed Eskimo huts, with the object of ascertaining whether the owners had returned, and other small trips. On November 15th the last ray of light had disappeared, and the thermometer registered —40° C. On January 21st, 1854, the first faint flush was sighted in the horizon, and on February 5th the thermometer registered —67° C.

Of the first two months of 1854 Kane himself says that they offered nothing of interest, beyond that observations were taken daily, that an infectious disease carried away 43 dogs before March 1st, and that the expedition suffered more or less from scurvy.

On March 19th the first sledge party started for the laying out of depots. It consisted of Sontag, Brook, Ohlson and three others, but on the 31st at midnight the three former returned, in a terribly exhausted state and hardly able to speak; they said they had left the others in their tent, on the hummocky ice, but exactly where they were unable to say.

Kane and eight men started at once. They were accompanied by Ohlson, who was placed on the sledge and immediately fell asleep, but upon waking up he was mentally deranged. After some hours' wandering the sledge stopped, the tent was raised, and the men received orders to spread themselves with a view to increasing the chances of finding the tracks of the missing party. The temperature was —45° C, and they all suffered terribly from thirst and cold, the taking of snow and ice into the mouth being followed by bleeding lips and tongues. After fourteen hours' march without food and drink, they at last succeeded in their search, and the vessel was reached after terrible suffering.

In the following weeks they were all confined to bed, suffering in various ways from the effects of the cold, and several with symptoms of lock-jaw which carried off one of them, Baker, on April 8th. They were all watching at his deathbed, when one of the deck-watch called out "People halloaing ashore." With the Eskimo hunter Hans Christian as an interpreter, Kane went to meet them, and their leader Metich went on board with Kane, while the other ten remained on the ice. After a short interview between Kane and Metich the others came on board, after having picketed their fifty odd dogs to their sledges, by means of driving their lances into the ice. Full of surprise and curiosity they went all over the ship and attempted to steal such trifles as they could get hold of. They gave some walrus meat and melted water in exchange for an iron pot, and after having eaten their parboiled or mostly raw walrus meat they lay down to sleep. The next morning they left, Kane having hinted to them that they should always attempt to be friends with such a powerful man; he also bought as much walrus meat as they could spare, besides four of their dogs, in payment for which they received needles, beads and cask staves. After they had gone, an axe, a saw

and some knives were missing, and, further, it was discovered that they had also entered the store house on Butler Island.

Next day the "Advance" was visited by five Eskimos on foot, but on further investigation it was found that their sledges were drawn up behind the hummocks. Kane says that these visits filled him with misgivings, as the Eskimos if hostile, might molest them seriously on future sledge journeys, and besides, it was important to keep up friendly relations if they were to get further supplies of walrus meat. So he received them well and on their departure gave them various presents, at the same time hinting to their leader Myouk that the former visitors would not be received again unless they brought back the stolen articles. The Eskimos went away proclaiming their innocence by signs, but, nevertheless, it proved that they had stolen a coal barrel from the store house, and that the three boats left from the first depot journey had been stripped of wood. From one of the Eskimos, the above-mentioned Myouk, who seemed more intelligent than the rest, Kane had obtained accurate information of their abode, Anoatok.

The month of April was nearing its close, and it was time to think of the summer journeys, but the state of health of all on board was bad, and this made itself felt in all branches of work. It was Kane's plan to follow the ice belt as far as Humbold Glacier, to secure pemmican from the October depot and then to proceed according to circumstances. Before his departure he gave orders regarding the Eskimos, who should be treated as kindly as possible, and Ohlson was left in charge of the brig.

Kane and his party started on April 27th with a sledge and the remaining seven dogs, while McGary had started a few days previously, with the object of laying down bread and pemmican at the depot on McGary Island. Two days after Kane had left the brig, he overtook McGary, and together they passed Marshall Bay, where the snow which lay very thick became so loose that it could not carry the sledges, and the men had to carry the cargo on their backs, at the same time beating a path for the dogs to follow. On May 4th they approached the glacier, but already on the 3rd scurvy, from which they had suffered during the winter, began to make itself felt, and when reaching the depot it turned out, to the despair of all, that bears had destroyed the pemmican depot and broken all the pemmican casks.

Kane himself suffered greatly from scurvy; his left foot became frost-bitten, so that it proved necessary to place him on one of the sledges, and as the scurvy spread, a speedy return became imperative. The unconscious Kane owed the preservation of his life to the others, who could hardly drag themselves along.

They reached the "Advance" on the 14th, but not until the 20th did Kane recover full consciousness. Before his departure Kane had removed the depot from Butler Island to the vessel, partly in order not to tempt

the Eskimos, and partly to facilitate shipping, in case it should prove necessary to leave the harbour, and in his absence Ohlson had stowed everything on board, so that the vessel could be made ready for sea at a few days' notice.

The first thing Kane did, after having recovered consciousness, was to send McGary to Lifeboat Cove to investigate whether the depot was secure, which proved to be the case; at the same time he brought the valuable piece of information that he had seen open water to the north.

The spring brought an abundance of salmon and several reindeer, but the plans of Kane were for the time being checked by the bad state of health of the crew; of himself he says that only by leaning on others could he go about and visit the sick.

On May 14th one of the crew died. Dr. Hayes was the only one who was entirely fit, and on May 19th, the first day that Kane felt sufficiently well to do so, he and Hayes discussed a plan for crossing Smith Sound to Cape Sabine, from where an attempt should be made to penetrate in a northern direction with the object of finding the hoped-for way out to the Polar Sea.

The dogs were in good condition, and Hayes started with one of the crew, Godfrey, as a driver, and at first made good progress; but already on the following day they met a wall of hummocks, 1.5 to 5 m high, and the dogs repeatedly burst their traces. It was the intention to head N. 20° W. in the direction of a certain headland, but owing to the obstacles in their way they made little or no progress; on the 23rd Hayes became snow-blind and could not proceed, but towards evening he recovered the use of his one eye and they continued in a northern direction with short days' journeys, until the evening of the 25th, when the latitude at midday was 79° 24′ 41′, and the western coast had been outlined. On the 26th the journey was continued, but shortly afterwards another of the party, William, became completely exhausted; the dogs were unable to pull, and the harness was so worn that they had to repair it with strips torn from the lower edges of their trousers. The problem was whether it was possible or justifiable to continue; seven of the ten days' provisions had been used, but the hope of a more speedy return and the prospect of killing a dog in an emergency to eke out provisions made Hayes resolve to continue. After supper Hayes started on foot in the direction of the headland, which he had all along been heading for, and after wandering for 13 km he found a level plain leading to the point he desired to make, and he made up his mind to go on, even if he were to carry William on the sledge.

On his return to camp he found that two of the dogs, which had not been fed since the preceding night, had eaten the lines, while a third had consumed its harness, and the damage had to be repaired as best they could. William, however, was now a little better, and after Hayes had got a few

hours' sleep, they set out for the headland, the first kilometres being passed with good progress. When they camped in the evening, Hayes was persuaded that they had identified the headland which formed the western point of the presumed sound at the north end of Smith Sound. On the 28th, in the morning, Hayes wanted to penetrate farther, in order to find a high point from which to take bearings to the identifiable points of the coast, but he was prevented by fog, and returned to the sledge, the position of which was lat. 79° 42′ 9″ N. and long. 71° 17′ W.

The return journey took place on the land ice and was attended by great difficulties. The sledge had to be lightened by leaving behind everything that it was possible to do without, with the exception of instruments. On May 30th the latitude at noon was 79° 6′. On the 31st, a short distance north of Cape Sabine, the course was shaped across the sound, and on June 1st the ship was reached. The dogs had been kept alive by the sacrifice of several articles of skin, and the result attained was a mapping of the coast followed as far as Cape Sabine.

Spring had come with sun and movement in the ice; walrus and birds appeared, but the general state of health was bad. Hayes was utterly worn out, Godfrey suffered from snow blindness, and according to the bill of health made out by Hayes immediately after his return, seven men were well, one (Morton) was convalescent, while the remainder suffered from scurvy or the consequences of this disease.

Nevertheless, Kane resolved to make a journey, the so-called North East Party, with the object of following the east coast and finding the sound leading towards the north, and of the existence of which he was quite convinced. The expedition was to comprise two parties, one consisting of McGary with three others, accompanied by Morton, who had orders to keep himself as fresh as possible and only attend to his own line of research, for which he was provided with instruments, while the second party was to consist of Hans on a dog sledge, to be joined by Morton after the two parties had met.

The first party left on June 4th with the task of filling up their provisions from the depot of last year and carrying the equipment for the second party to the base of the large glacier (Humboldt Glacier) which was to be mapped, as well as the coast traversed. The going, which was good on the first day, soon changed, and the soft snow made it difficult to haul the heavily loaded sledge; also, several of the members of the party suffered from snow blindness, so progress became slow. After having passed Glacier Bay, Marshall Bay and Chimney Bay, they found the depot destroyed by bears, and the same was the case at Cape Russell. On the 10th they had an encounter with a bear, which surprised them, unarmed, in their tent, but they managed to get hold of a gun, and the bear was killed, supplying them with provisions and food for the dogs.

On the 14th the latitude attained was 79° 12′ 37″, and the depot laid out at that place was found to be undamaged. Its contents were loaded on sledges, as it was feared that the most northerly depot was destroyed, and so it eventually proved to be. On the 16th the glacier was reached; here they found Hans with a sledge and dogs, and on the 18th the parties separated; the former returned on the same day, reaching the vessel on the 25th, exhausted and suffering from snow blindness. The destruction of the depots had necessitated the abandonment of the projected mapping of the glacier, but the traversed coast was charted.

The second party which, as already mentioned, started on the 18th and, after having made 32 km, camped for the night at a distance of 11 km from the glacier, but on the following day the ice-difficulties increased; in Peabody Bay they met a number of icebergs, which lay so close as to block the way, and so they had to walk round them. Not until the 21st did the ice improve, and they saw a headland between which and the sound on the west side there was an opening. On the following day they approached the headland, but the ice was so rotten that the dogs would not proceed; a fog came on, so they sought the solid land-ice, and when the fog lifted, they saw the sound, in the middle of which there was open water. Hans declared that if he had not seen birds on the water, he would not have believed his own eyes.

After having, with great difficulty, passed the headland (Cape Andreas Jackson) they followed good land-ice, but were detained by a gale from the north until midnight on the 23rd, and after having followed the coast for some time they fell in with hummocky ice, which prevented all penetration. Hans and Morton tied the dogs to the sledge and went ashore in a northern direction, until they were stopped at the entrance to a bay from where, in the north, they saw an island and a promontory. After having realized the impossibility of proceeding, they returned to the dogs, which they again left on the following morning in order to go ashore. After a march of 14 km they saw a she-bear with a cub, which they decided to attack at once; they received unexpected assistance from five of the dogs which had torn themselves loose and followed the tracks of their masters; and both bear and cub were killed. The former was skinned and given to the dogs, whereas the cub was reserved for the return journey. Then they continued and arrived at a small inlet full of hummocky ice where they saw that the island they had previously sighted was in reality two islands, which were named after John Franklin and Captain Crozier. After having passed this inlet Morton proceeded in the direction of the promontory (Cape Constitution), but the land-ice became narrower and narrower and disappeared entirely below the promontory, the base of which was washed by the sea. The coast was bounded by steep cliffs, which he tried to ascend, but after having reached a height

of a few hundred metres he had to give it up, bitterly disappointed that it proved impossible to get round the promontory to see whether there was land on the other side.

On the 25th they started on their return journey, after having measured she latitude of the place, *viz.* 80° 02′, the highest latitude which they had tucceeded in measuring, as the sky had been overcast on the two preceding days. The going was very difficult owing to the quick melting of the snow, which a few days later would have made the journey almost impossible. On July 4th they were back at the brig.

The valuable results of this journey consisted in the survey work done, in the discovery of the channel (Kennedy Channel), with the open water, in the observation that a current from the south in this channel caused the presence of ice, and also in information relating to the rich animal life of birds and seals along the channel. From the results obtained Kane finally drew the conclusion that the journey showed how the climate within an historical period had become colder, his reason being partly of a geological nature and partly that huts had been found along the travelled distance now blocked by the ice, so that the inhabitants would be cut off from sea hunting.

The time for sledge journeys was now at an end. The "Advance" was still ice-bound, and great misgivings were felt at the prospect of the coming winter, for never had a crew been less equipped for a second arctic winter, being broken in health and short of provisions and fuel. Nevertheless, Kane had hardly any choice but to stay, as it would be almost hopeless to attempt to reach Upernivik or Beechy Island with the exhausted crew, and to desert the brig, while there was yet hope of saving it, would be unmanly. Kane resolved to remain.

After a vain attempt at finding a way out for the ship in a south-westerly direction, he conceived the idea of trying to reach Beechy Island in a boat, so as to get into touch with the squadron of Sir Edward Belcher, and if he failed in this attempt to try to reach Wellington Channel. He laid his plan before his associates, who heartily approved of it, and to accompany him he chose five men who were in good health; the old whale-boat was improved for the journey with a keel, two masts and a sort of half-deck, consisting of waterproof canvass, and finally a steering oar in place of a rudder, and when finished it was placed on a sledge, which was to be pulled by the whole crew, while Kane and Hans pulled a sledge with provisions, etc.

The ice was very uneven and covered with water pools; the sledge on which the boat was placed broke down, but at last the open water was reached: the coast was followed in a southerly direction between floating ice; the point where the life-boat had been left behind was revisited, and it was found to be intact. When they approached Littleton Island, they fell

in with great quantities of ducks and eiderfowl and secured large supplies of provisions, but in the night a gale sprang up from the north; they barely escaped being wrecked, and from now onwards they had a severe fight against wind and pack, until the crew were utterly exhausted for lack of sleep. On July 1st they were stopped by an impenetrable mass of ice, and from the top of a 36 m high iceberg Kane saw that it lay solid to the south and west for a distance of 42 km. He realized that he had reached the eastern boundary of the pack which at that time of the year divides the open water in Baffin Bay into two distinct bodies, so further penetration towards the south-west was impossible, and he resolved to return to Northumberland Island. There they again found great quantities of birds and some Eskimo huts which proved to have been lately inhabited, and here the crew recuperated somewhat and—as Kane himself said—grew "fat and strong upon the auks and eiders and scurvy grass."

About August 7th the expedition was back at the "Advance", and during the following days various attempts were made to get the boat clear by means of blastings; but the only result was that it was moved a little and righted, and it seemed that a second winter in the same place was inevitable. On August 24th Kane communicated his resolution of staying another winter, pointed out the extreme risk of trying to reach open water, alluded to their duty to the ship, but left it to all on board to make their own choice. Eight of the seventeen survivors resolved to stay, *viz.* Brooks, McGary Wilson, Goodfellow, Morton, Ohlson, Hickey and Hans.

To the others Kane gave their portion of the scanty provisions, and on August 28th they started south, led by Hayes, one of them, Ridley, returning a few days afterwards.

Kane now made all preparations for wintering; the small stock of fuel made him resolve to follow the example of the Eskimos, *viz.* to turn the brig into a sort of igloo by making a compartment 5 m square and covered from ceiling to floor with moss and turf. The floor was to be covered with a layer of earth, and above this there was to be a two metre thick layer of Manilla oakum, which in its turn should be spread with a canvass carpet. This compartment, which was to be the sole abode of the remaining ten men, was finished on September 10th, and then they began to strip the brig of as much of its woodwork as could possibly be spared for fuel. On September 11th Kane made an excursion in order to get seal, but the sledge went through the thin ice and was lost with everything in it, while Kane and Hans narrowly escaped being drowned.

While Kane was away on his attempt to reach Beechey Island, the Eskimos who had formerly been there had reappeared, and on his return he made an arrangement with them for the delivery of walrus meat and the payment for it. By this and their own hunting the expedition would be provided with fresh meat, but the Eskimos never came, and on October 13th

Morton and Hans were sent to Anoritôq in order to learn the reason. After a journey of 91 km they found two huts in one of which Myouk lived together with his parents and his brother and sister; they were well received and spent the night in the warm hut, sleeping, like the others, naked on skins, and on the following day they took part in a walrus hunt, where an animal was killed. On the 21st Morton and Hans were back at the brig with their share of the animal.

On the 24th the arrangements for raising the brig were completed; she had been lifted one metre, and now lay as in a sort of "ice dock," which work had been absolutely necessary, as she was unable at low water to bear the ice masses adhering to her.

From now onwards all efforts were directed towards guarding the small party against the winter cold by practising the greatest economy as regards fuel. The fire was first exstinguished for four hours in the night, but later on, when the temperature fell, it had to be kept burning day and night; the carpenter, however, comforted Kane by saying that it was still possible to strip the brig of 7 or 8 tons of wood without making her entirely unseaworthy. At the same time most of the men were scurvy-ridden in their bunks, while Hans took care of the hunting, so only Kane and three others were left to do the work on board.

On December 12th Kane was roused in the night by the cry of "Eskimos again!" It turned out to be Dr. Hayes and his followers who were brought back by the Eskimos on their sledges, in a state of terrible exhaustion. The Eskimos had been very helpful and kind, had driven as fast as they could, but seemed to have something on their minds. By means of an interpreter Kane was informed that his men had taken some fox-skins for clothing; from policy as well as from a sense of moral duty he paid the Eskimos liberally with needles, knives, etc., and after a solid meal they left for home.

The uncalculated accession of numbers made it necessary for the sake of ventilation to move the cooking lamps outside the dwelling room, and this came very near to causing an irreparable accident. One of the watchmen had failed to comply with the order "no uncovered light," and in a moment the cooking room was in a blaze, but fortunately the fire was exstinguished and no great harm done.

Christmas was celebrated in as festive a manner as possible, each drinking to "absent friends" in his small portion of the last bottle of sillery.

Before Christmas Kane had planned an expedition in a southern direction to the nearest Eskimos, with the object of getting more walrus meat. Only one of the suffering crew could be spared, and Kane and he started on the 29th. On January 2nd, 1855, the dogs were almost exhausted, but still they managed to reach the empty huts at Anoritôq, where they were detained by a gale for twenty-four hours. When the storm was past, they wanted to continue, but had to give up the attempt, as the dogs were entirely spent;

so the two men had to walk, driving the dogs in front of them, and thus, suffering greatly, they reached the brig.

Owing to the greatly reduced supply of fuel it had become necessary to heat the room by means of lamps, but the soot and smoke which was the consequence of this manner of heating was anything but healthy; there was a scarcity of dogs food, and the surviving teams had to be fed with their dead comrades; the state of the men became worse and worse, only Kane and two others being able to work. As Kane himself wrote on January 17th "the present state of things cannot last," and so he resolved to make another attempt at reaching Etah, which was 145 km distant, though the temperature was —45° C., and the dogs were weak with want of food. On January 22nd he started together with Hans, who just before the start caught a fox, which was divided among the sick. On the 29th two of the dogs gave out, and after fourteen hours' march Kane and his attendant reached the old hut in a snowstorm, with a rising temperature, which made them prisoners in the hut for a couple of days. The fallen snow prevented further progress, and although Kane, from an elevated point, sighted level ice ahead, lack of provisions forced him to go back to the brig, where his return without meat caused great disappointment.

By various remedies Dr. Hayes tried to alleviate the suffering crew; now and again some rabbits were caught and brought temporary relief, but otherwise the diary of Kane is taken up with descriptions of the terrible state on board. On the 22nd hope and courage was stimulated by the news that the sun had begun to gild the remote peaks; on the 23rd Hans brought in a reindeer, and all on board got a good meal, while, on the other hand, two attempts to communicate with the Eskimos in the south failed.

On March 4th the last meat was distributed, and Kane's diary for the following days is terrible reading, being the blackest possible record of increasing weakness and illness. On the 6th Hans started with a sledge and the two remaining dogs; he returned on the 10th with the news that the inhabitants of Etah were entirely broken down with starvation, but he encouraged them to go out walrus-hunting, and with his rifle he shot a walrus, of which he brought home his share, to the great relief of all on board. He also brought Myouk, and together they went south on the 13th.

Immediately after their departure Godfrey deserted. Kane had long been suspicious of him, and he now feared that it was his idea to try to overtake Hans and rob him of sledge and dogs, which would mean a very serious loss to the expedition.

On April 2nd a man was seen to approach the ship with a sledge and dogs. Kane and Bonsall went to meet him, thinking that it was Hans, but it proved to be Godfrey, who turned and began to run off in a southern direction, when he saw the two men approaching. He was overtaken and then told them that he had been at Northumberland Island, that Hans lay

ill at Etah and that he himself had resolved for the remainder of his life to live with the Eskimos. With his pistol Kane forced him to go back to the ship, but he refused to go on board. Kane left him in the hands of Bonsall, who was provided with a rifle, and went on board for irons, but he had no sooner set foot on board than Godfrey made his escape, nor was he hit by the shot fired after him.

Kane was on the brink of despair. Sledge and dogs were in the hands of Godfrey, and Hans had been away for a fortnight. However, Godfrey soon came back with dogs and sledge and walrus meat, probably with a view to taking Blake with him, as the others thought that he had for some time also been contemplating flight. Kane informed them that desertion would be severely punished, and the walrus was taken on board.

It was a very serious problem for Kane whether he should go in search of Hans or stay with the sick. However, he made up his mind to go, and left with a minimum of luggage on his sledge. Off Refuge Harbour he met Hans, with whom he stayed for a night at Anoritôq, and the latter told him that he had reached Etah with Myouk, had killed five walrus together with the Eskimos, but had afterwards become ill from the strain. He had deposited part of his catch on Littleton Island and had sent Godfrey on with the remainder to the ship. Godfrey had tried to persuade him to go south with dogs and sledge, but he had refused, and he had also refused to lend him his rifle.

On April 11th Hans started again to fetch the depot at Littleton Island, being at the same time entrusted with the task of finding some dogs for Kane, who could not give up the idea of a speedy journey to Kennedy Channel. He was back on the 17th with rabbit and walrus meat, and with him came Metek, the chieftain of Etah, accompanied by Pauluk. On the following day Kane returned from Etah where he had been on a small visit, and by a stratagem had managed to bring back Godfrey, who again had deserted; his return was hastened by the information he had received from Hans that the condition of McGary had become desparete, but on his return he found the crisis past and dispatched Hans to Pitoraivik in the neighbourhood of Cape Alexander with orders to try and persuade Kalutunak to go with him to the brig.

As contrasted with the preceding year the ice lay solid over the whole of the visible expanse, thus minimizing the hope of getting the ship free, but, nevertheless, the preparations went on, being made easier by an improvement in the health of the crew. On the 24th Hans returned with great quantities of walrus meat and accompanied by three Eskimos, each with his dog and sledge. Their leader was Kalutunak who, although rather overbearing in manner, declared himself willing to take part in an expedition with Kane, as the latter still desired to subject the Kennedy Channel to further investigation.

The expedition started, consisting of Kane, Hans with his rifle and three Eskimos with their sledges, the luggage being limited to walrus meat and the lances of the Eskimos. On the second day a bear came into sight; it was killed, and part of it was eaten, which necessitated a day's rest, as the Eskimos had partaken too freely of the fresh meat. On the following day the journey was resumed, but there were so many bears that the Eskimos would not give up hunting them, and as Kalutunak declared that Kane had no right to prevent their providing for their families, he had to give in and spent a couple of days in investigating the Humboldt Glacier, while the Eskimos went hunting, but, being unable to get any assistance from them, he at last returned, and after one more unsuccesful venture, gave up the attempt.

The preparations for leaving the brig were now in full swing; two boats were made ready and placed on sledges provisions, arms, and instruments were stowed, and the necessary clothing was made. The departure was fixed for May 17th, and after a solemn leave-taking the expedition set out, only Kane and twelve of the crew being able to do any work, while four had to be driven, and Hans followed in his own sledge with the Eskimo who had been left behind. Brooks was given the command of the two boats, and on the 24th they reached First Ravine, to which Kane had brought sleeping bags for the comfort of the suffering.

By slow stages they were then brought to Anoritôq where, before his departure, Kane had equipped a hut for them, but as the Eskimo who had consented to stay behind and help, had thrown away part of the provisions in order to lighten the sledge, Kane was obliged to make several trips back to the vessel, to bake bread, etc., while Godfrey was sent to Etah and returned with Metek and a large provision of walrus meat.

When the last flour had been used up, Kane, once more accompanied by Hickey, went to Etah for assistance, but near Littleton Island they were overtaken by a severe snow storm; they sought shelter behind a projecting cliff, Cape Misery, but the storm continued, and at last they had to return to the slowly progressing boats. Kane remained there, but sent Morton on with his sledge to Etah. On June 5th the boats continued their weary progress through the sodden snow, one of them barely escaping going through the ice. On the 6th Morton returned from Etah with fresh dogs and walrus meat, while Kane returned to the brig with the fresh dogs and then proceeded to the sick at Anoritôq.

The ice was very unsafe, and Kane felt great anxiety for the boats, so he soon returned to them, and when meeting them, he learnt that one of them on the previous day had gone through the ice, and only by almost superhuman efforts had been saved by Ohlson, who a few days afterwards died from the injury sustained.

Hans, who had been so very useful to the expedition, was missing. At

Pitoraivik he had fallen in love with a young girl, and now he was supposed to have gone after her. In his stead Kane received assistance from various Eskimos who occasionally joined the expedition. Besides the two large boats there was a small one, called "Red Erik," which contained all the documents of the expedition; collections and everything else Kane had, to his intense regret, been obliged to leave behind on the brig. One day it happened that the boat went through, but before Kane arrived on the spot, one of the crew had already secured the chest containing the precious papers, and in the end boat and load were saved without loss of life. At last Lifeboat Cove was reached, where the depot laid down by McGary was found in good condition.

From an elevation Kane saw the open sea, and most of his exhausted associates were of opinion that an attempt should be made at once to reach it, but Kane considered it safer to follow the coast, all the more so as the dogs were now in good trim. Upon the whole he tried to show as brave a front as possible, principally because he did not want the Eskimos to get too strong an impression of the state to which the expedition was reduced. He said that the vessel had only been deserted for the purpose of a hunting expedition and concealed the death of Ohlson from them by sending them away to get birds for provisions. The dead man was buried on a headland, which was named after him, and the journey was resumed.

The Eskimos brought great quantities of auks and were generally helpful in the transport of the boats and the sick members of the crew, and on June 16th a halt could be called about 5 km from the open sea, on the north side of Baffin Bay.

The boats, which had sprung many leaks during the passage on the ice, were repaired, and everything was made ready for the journey. All the Eskimos assembled to say good-by and were given gifts in the shape of knives, scissors, files or the like, while the travellers, in their turn, received great quantities of birds. After a melancholy leave-taking the boats were hauled down to the open water, when a storm broke, and the departure was delayed until the 19th.

The wind had calmed, and the sea lay like a mirror when the final start was made. Kane with his party was in one of the boats, the "Faith," Hayes with another party in the "Hope," while three others followed in the "Red Erik." When Cape Alexander was passed, the wind began to freshen, and Kane resolved to reach Sutherland Island, but was stopped by the ice, and the course was shaped for Hackluyt Island. A choppy sea from the south-east filled "Red Erik," so the crew were obliged to leave it, and as it proved impossible to unload it, it was towed by the others. At nightfall they succeeded in reaching a floe, alongside which they made fast, and soon afterwards they all slept the sleep of exhaustion. With varying luck they proceeded for a couple of days, when once more a storm broke, and an iceberg came

down upon them threatening them with destruction. Then, as by a miracle, an opening appeared in the ice, and the boats got through to the coast, where a large cave provided rest and shelter to the tired men, whose strength was all but spent. In this place there were, however, great numbers of eiderducks, and during the three days and nights which were passed here, eggs were gathered at the rate of twelve hundred a day. On July 3rd the weather again became so calm as to permit them to leave "Weary Men's Rest," and in the evening they reached Wolstenholme Islands. The following days were a constant fight against ice and short rations. After 52 hours of strenuous efforts an open lane was reached, and on the 11th the boats were drawing near to Cape Dudley Digges.

For a moment Kane thought that their troubles were at an end, when a glacier, which was not marked on their maps, came into sight, the calf ice of it extending far out. Their first resolve was to double it, as the crews were too weak to attempt another tracking through the hummocks, but on second thoughts Kane climbed an iceberg and saw that the winter ice still lay unbroken towards the south. He then made up his mind to follow a narrow lead along the coast, and the boats landed at a projecting point with a tall cliff behind it. To the south there was a small valley with fertile vegetation and then again a 11 km broad glacier. On the cliff there was abundant bird life, and the killed birds, together with eggs and cocklearia, yielded some splendid meals.

In this place, which was named "Providence Halt," the travellers remained until the 18th, when at last the ice gave hope of progress. After several minor accidents they again shaped their course along the shore, passed Crimson Cliffs with its rich bird life, and found a kind of turf which could be used as fuel. In lat. 76° 20′ N. they found a village consisting of deserted and partly collapsed Eskimo huts. On the 21st they reached Cape York, but a party which had been sent out to Episak behind Cape Imilik to see whether there were any Eskimos, returned with a negative result. The provisions were now calculated at 640 lbs besides dried birds, and after "Red Erik" had been cut up for fuel and a cairn erected with a report, they passed with great difficulty along an open lead, until on August 1st Devil's Thumb came into sight. In the interior of Melville Bay there was still open water, and in order to shorten the way Kane gave up the attempt to try to wind his way through the pack, but resolved to continue through the archipelago of small islands at the head of Melville Bay. A few days later the boat met an umiaq from Upernivik, which was bound for Kingigtoq to fetch blubber. The joy at the meeting was indescribable, and after the first questions had been answered, Kane received information that two ships had gone north to relieve him. Twenty-four hours later, after forty-eight days of dangerous sailing and a daily struggle for life, the boats reached Upernivik.

On September the expedition left Upernivik on board the "Mariane," one of the vessels of the Royal Greenland Trading Company; they called at Godhavn, where they stopped as long as possible in the hope of receiving news from Lieut. Hartstene, the leader of the auxiliary expedition, who had not been heard of since July 21st. On the same day that the day of departure was finally settled, Hartstene arrived with his two vessels, and the meeting between the two leaders was a very pathetic one. In spite of ice difficulties, Hartstene had investigated the western as well as the coast of Baffin Bay and had learned from the Eskimos that Kane had left the "Advance" in boats with the whole of the crew. From Godhavn Kane departed for America in Hartstene's vessel.

The results of Kane's expedition were very considerable; besides the mapping of the west coast of Greenland from Cape Alexander as far as and including Humboldt Glacier, scientific facts had been collected regarding the flora, fauna and ethnography of the distance traversed, and meteorological, magnetical and tidal observations had been undertaken.

In 1859 Dr. Hayes laid before the American Association of Science a proposal for an expedition, the object of which was, from a station in Kennedy Channel, with ships and sledges to investigate the north coast of Grinnel Land and Greenland. The expenses of the expedition were to be defrayed by voluntary contributions, but as these did not come in as freely as had been expected, Hayes was obliged to reduce his original plan of employing a steamer as well as a sailing ship, and to limit himself to the latter. The "Spring Hill," a fore and aft schooner of 180 tons was bought and rechristened the "United States;" she was also strengthened and provided with ice-covering, Hayes profiting from the experience he had acquired as a member of Kane's expedition in 1853—55.

In July, 1860, Hayes left Boston with August Sontag as astronomer and second-in-command and George as his secretary. Further, there were Henry Redcliffe, assistant astronomer; McCormick, sailing master; Henry W. Dodge, mate, and a crew of eight men.

The first place visited was the settlement Pröven where the expedition made a stay of one day in order to get dogs. Pröven was left on August 12th, and on the same day the expedition reached Upernivik where Hayes, by sudden death, lost one of his best men, the carpenter Carruthers who had been with Kane on the first Grinnell Expedition. Here the expedition was joined by six men, three of whom were converted Eskimos and did duty as hunters and dog-drivers, and a team of dogs was taken on board.

As soon as the ship had left the harbour, it met a number of icebergs which made navigation difficult and caused frequent collisions. On the 21st, however, it succeeded in entering a small harbour Tasiussaq, where Hayes was in communication with the Eskimos. On the 22nd they proceeded,

shaping their course for Melville Bay, which was traversed in 55 hours with several narrow escapes from icebergs, until off Cape York where Hayes went ashore to find Hans (from Kane's Expedition), in which he succeeded; Hans was taken on board with his wife and child, and the voyage was continued. Without any particular obstacles they reached the entrance to Smith Sound on August 28th and headed for Cape Isabella, but soon a heavy pack, many of the floes being up to 3 m in height, stopped the vessel, and the ice extended as far as the eye could reach. A violent storm broke loose from the west, and only on the 30th did the ship anchor off the coast. The gale continued, and in the night between August 31st and September 1st the ship was adrift and struck against an iceberg, suffering much damage. Sails were set, but the main-sail went to pieces, and soon afterwards it became calm. The temperature was $-5.5°$ C., and everything on deck was covered with ice. After repairing the damage Hayes resolved to follow the coast of Greenland, in the hope of being able to reach across the sound. A new storm forced him to seek shelter behind Cape Alexander, and after another attempt at penetrating the ice to Cape Isabella, in the course of which the ship was beset by the ice and lifted, it again got clear and Littleton Island was reached. Ice and cold increased to such an extent that Hayes, in a great hurry, sought Hartstene Bay in order to winter, bitterly disappointed, because he had been frustrated in his plan of reaching across the sound, all the more as the vessel had suffered so much that it was not fit for another attempt in the following year. The harbour where the ship lay was called Port Foulke.

The necessary work for the wintering of the ship began. Sontag, together with three others, was entrusted with the scientific task; Hans and another Eskimo, Peter, with the hunting, while the mate, Dodge, with the remainder of the crew took charge of the work on board the ship and the stowing of the cargo in a provision shed ashore. Hayes himself was very pleased with the prospect for the coming winter and particularly with the ample provisions of game, reindeer, hares and foxes, and though, during the voyage, many of the dogs had succumbed, there were still enough left. With the decreasing temperature the ice lay solid over the whole of the harbour, thus making the ship more secure than before when it had twice been set against the cliffs.

The first part of October was spent in practising sledge-driving and hunting, as well as various scientific work and the investigation of the numerous Eskimo graves found. On the 22nd Hayes started on an expedition which had been planned to the glacier at the head of the fiord, and he was accompanied by seven men with sledges on which were a tent, a cooking apparatus and provisions for a week. The ascent was difficult and not unattended by accidents, but shortly afterwards the ice became smooth, and after wandering 25 km the tent was raised for the night. On the follow-

ing day the party covered a distance of 48 km on smooth ice, but after a while there came a 0.9 m deep layer of snow with a crust, which broke under their feet and made the marching very difficult.

On the following day they covered 40 km under the same conditions, but the state of the party warned Hayes against proceeding; the temperature fell to —34° C., and when a violent storm broke from the quarter in which their route lay, they were forced to stay in their tent. The temperature further fell to —36° C.; they could not sleep, and after a halt of some hours they broke tent with numb hands and started on their return journey, suffering badly from cold. The height attained was 1500 m, and driven by the wind they now covered a distance of 64 km, when the tent was pitched at an altitude which was 900 m lower than at their last camping site. The storm had lulled somewhat and the temperature rose by 12°, and thus they reached the vessel on the following evening, having accomplished the first trip on the inland ice.

During the absence of Hayes, Sontag had measured a base of 273 m and determined the distance to Cape Alexander, Isabella and Sabine, and on November 3rd he started for Rensselaer Harbour with two sledges for the purpose of determining the longitude of the harbour, but the attempt had to be given up halfway, and he returned after a very exciting bear hunt. On this trip and also in the harbour itself it was observed that the open sea reached as far as the firm land ice. The temperature on November 10th had risen to —12° C.

The life on board seems to have been quite pleasant, the temperature in the mess rarely being below + 15° C. and here, when the work of the day was done, the members of the expedition assembled in order to play cards or chess. They also issued a newspaper, "The Port Foulke Weekly News."

On November 13th Hayes mentions a strong rise of temperature which to his surprise lasts in spite of a heavy storm from the north-east, but on November 17th it is —23° C. A still more peculiar change of temperature occurs on November 28th and 29th when it rose to —18° C. and suddenly again fell to —27° C., which change was accompanied by a heavy fall of snow followed by rain, which otherwise only falls in July and August.

At the beginning of December a great misfortune occurred, in that an epidemic broke out, carrying away one dog after the other. Hayes, whose plans for the future depended upon the dogs, was in despair. He began at once to think of replenishing his stock, and at the end of December Hans and Sontag, with the remaining uninfected nine dogs, were sent to Sarfalik with orders to proceed to Northumberland Island if they did not meet Eskimos there.

On January 2nd, 1861, the last of the teams died, and Hayes tried to comfort himself for the loss of his favourite dog by training a young fox,

in which he succeeded. January was very stormy, and the winter snowfall during the first few days of the month amounted to 124 cm.

More than a month had passed since the departure of Sontag and Hans, and Dodge was sent out to try to find their track; it was followed as far as Cape Alexander, a distance of 7 km, when it suddenly stopped, the ice having drifted off in the month of December. On January 29th, in spite of a temperature of —42° C., Hayes was ready to go south, when the call sounded: "Two Eskimos alongside."

The first piece of information received was that Sontag was dead, and after the Eskimos had been given some food, they further communicated that Hans was on his way to the ship, accompanied by his wife's parents, but that they travelled slowly, as they had lost several dogs. Two days afterwards Hans himself appeared but only with the brother of his wife, her parents with their dogs having broken down in the neighbourhood of the glacier. A party was sent off with the dogs of the Eskimos and a large sledge, which brought back the parents and the dogs, more dead than alive.

When Hans recovered somewhat, he told that he and Sontag had passed Cape Alexander on Sutherland Island and headed for Northumberland Island, when 6 to 8 km from the former island Sontag had begun to feel cold and had run ahead to get warm again. Hans, who for some reason or other had been detained for a moment, hastened to overtake him, but all of a sudden he saw him disappear through the ice. He hurried up and succeeded in hauling him out, and together they returned to a hut which they had just left, without Sontag changing his clothes; at first he ran beside the sledge, but after some time he sat up on it. When they reached the hut, Hans discovered that Sontag was stiff and mute, and though he did all in his power to revive him with warmth and coffee, he was dead. Hans closed the hut against foxes and continued to Northumberland Island. The natives had left this place, and Hans proceeded to Natsilik, which he also found deserted, and then drove on to Itivdleq. Here he met the two Eskimos and his wife's parents, who joined their dogs with his, and together they returned to the vessel. The loss of Sontag was a severe blow to Hayes, and he made Hans repeat the report of his death, which in spite of certain rather peculiar points, he was fain to believe in the end.

The two Eskimos left on February 2nd, promising to return when they had provided for their families and tried to get dogs. About this time reindeer and foxes again began to appear, and the open sea came nearer and with numerous walruses. The Eskimos gradually found it too hot on board and built a snow hut ashore; Hans' wife was an excellent sempstress for the crew and was paid with gifts consisting of needles and knives. On the 12th the sun again had risen above the horizon, and soon afterwards three Eskimos arrived with two sledges, one of them, Kalutunak, with excellent dogs. They remained on board for a few days, and when they departed, they left

four dogs and promised to bring more. They had hardly left when two other Eskimos arrived, leaving two dogs.

Five days after his departure Kalutunak returned with his wife and four children and their few movables on the sledge; the temperature was —34° to —41° C., but this did not seem to inconvenience the family. Another Eskimo, Myouk, also appeared with his wife and child, but in a poor state, and thus the number of Eskimo guests gradually increased, until there were in all seventeen men, women and children, and some of them went out hunting for the expedition, with good results.

After Hayes had ascertained the ice conditions at Cape Alexander, the body of Sontag was fetched back and buried with all solemnity. On March 16th Hayes started with two sledges and a small party consisting of Kalutunak and another, the object of this journey being to decide whether, in order to reach Grinnel Land, it was necessary to follow the coast of Greenland (Kane's route), or whether it was possible to go direct across the sound from Cape Hatherton. Eight km from the ship one of the sledges went through with its driver and dogs so they had to return to the ship, but they started again after a short halt, and in the course of the day they reached Cape Hatherton, where they camped in a temperature of —41° C. The next morning they started again and reached Fog Inlet, where they found the cairn erected by Capt. Hartstene when he was up there to search for Dr. Kane, and they named the place Cairn Point.

The view from there was not encouraging, the ice being extremely rough and unfit for the sledges. At Cairn Point a depot was made of all they could possibly dispense with for a six days' trip, and on the following day they continued, in a northern direction, across very rough ice, on which it was almost impossible to make progress. The night was spent in a hut dug into a snowbank, but in spite of the lighted lamp it proved impossible to raise the temperature within to more than —34° C. With this temperature the snow became as hard as sandstone, the great resulting friction, however, being diminished by wetting the runners, which, when the water froze, became very smooth. The water was obtained by Kalutunak melting snow in his mouth and applying it to the runners, as has been mentioned above, with very good effect. Hayes himself says that it is unnecessary to give details of the journey day by day; he realized that it was impossible to proceed along the west coast of Greenland, the ice being of quite a different nature from what it had been during the journeys of Kane, and he calls it the Rocky Mountains on a reduced scale. He also mentions how he recognizes every point along the coast, and that he visits the graves of two of his late comrades, but when he asks the Eskimos about the fate of the "Advance," he receives contradictory answers. The home journey took place in a temperature of —37° C. with a strong gale from behind, and during the following days the sledges came and went between the

ship and Cairn Point in order to complete the depot for the summer journey.

On April 3rd Hayes started on his summer expedition, followed by 12 men with two sledges, the "Hope" and the "Perseverance," and in a temperature of $-36°$ C. the course was shaped for Cairn Point which was reached on the 6th (temperature $-12°$ C.) The journey had been easy enough as far as the sledges were concerned, but some difficulty had been caused by the transport of the boat, which had been carried along on a specially equipped sledge. Hayes ascended a height, but the view before him was rather a dismal one, the sound as far as he could see being filled with hummocky ice.

On April 7th there was a snowstorm with a violent fall of temperature, which for three days detained the party in their snow hut and stopped all travelling for them. When at last the weather calmed, the first task awaiting them was to fetch all that had been left at Cape Hatherton, including the boat, and this being accomplished, the expedition once more started across the sound in a westerly direction, the large sledge with the boat being pulled by the men, the two smaller sledges by the dogs. The obstacles in the shape of hummocky ice were almost indescribable, and on the 27th Hayes realized the impossibility of carrying through the expedition in its entirety; so he resolved to continue with a party consisting of three men, two sledges and fourteen dogs, while the remaining were sent back.

On June 3rd Hayes was back at the schooner; he had landed at Cape Hatherton, but from there he and his followers were obliged to try to reach the ship on foot, as the dogs were too exhausted to pull the sledges; only three of them had strength to follow; three returned later, but four never turned up.

All was well on board, with the exception that McCormick thought that the vessel had suffered too much to be able to go to sea. A few days afterwards Hayes himself undertook a tour of inspection and arrived at the conclusion that, by various measures, it would be possible to make the ship seaworthy, but not for a passage through the ice, and so he had to abandon his plan of taking her from Smith Sound through Kane Basin into Kennedy Channel. The number of dogs were reduced to four, and so Hayes resolved that the only sensible thing would be to return home and come back the following year with a steamer, for from what he had seen in the course of his last journey, he felt persuaded that once at Cape Isabella, it would be an easy matter to penetrate north and to find a free route to the Pole; now he would only wait till the ice broke up, and the ship got free.

Spring had come with an abundance of animal life and a temperature of $-1° 7'$ C. The schooner was equipped for the sea journey and the rigging set up, the Eskimos all the time hovering in the neighbourhood. Pendulum and magnetical observations were taken, and at fissures in the ice dredgings

were made with excellent results, while Hayes was occupied in studies of the glacier. On June 21st the open water was only one mile from the schooner; the temperature was + 8° C., and there were frequent showers of rain, but on the 26th the weather changed to hail and snow with a gale from the south, which began to set the ice into motion round the schooner. The following days Hayes spent in excursions to various places, with the object of identifying the uplift of the coast of Greenland north of lat. 76° N.; he also took part in a very dangerous hunt, and made other excursions with a view to geology, zoology and botany. On shore he raised a cairn in which a report was deposited and, on behalf of the Eskimos, Kalutunak promised to keep it in preservation.

On the 11th the ice in the harbour was set in violent motion, not without danger to the schooner, and at last the latter was really afloat. After having taken a hearty leave of the Eskimos, whom they owed so much, the schooner, on July 14th, left the harbour with a faint breeze and constantly meeting icebergs.

Hayes could not resist the temptation to make one more attempt to reach the coast of America, and so he shaped his course for Cape Isabella, but was soon stopped by a heavy pack and found a safe anchorage between McGary and Littleton Islands. A few days afterwards the attempt was renewed, and the ship reached land at Gale Point, 15 km south of Cape Isabella, where Hayes ascended a height. He realized that it would be folly to try to go north with the ship, but he was more than ever resolved to return the following year with a steamer. After many ice difficulties he reached Whale Sound, which he was most desirous of exploring; the inner fiord was investigated and called by the name of Inglefield Gulf, and also the village Itivdleq on the south side of the sound was visited. Here there lived about 30 Eskimos, including Kalutunak. Hayes made several excursions, among others to the Tyndale Glacier, which was named by him.

In fair weather the vessel left Whale Sound; a final attempt to reach the coast of America was frustrated by storm, and the course was shaped for Melville Bay. After a rather good passage Upernivik was reached on August 15th. From Upernivik the vessel proceeded to Disko and thence back to Boston.

Hayes' explorations along the coast of America, with their frequently very misleading determinations of places in North-west Greenland, are not to be mentioned here. But, apart from that, he has contributed largely to the geography of Greenland and has given valuable geological, zoological and botanical information. Further, he has contributed to the knowledge of the Eskimo tribes living in those parts and has, *inter alia*, demonstrated how this race gradually disappeared from regions where it used to live. His results are in his own report on the journey summarized in the following six points:

1) I have brought my party through without sickness, and have thus shown that the Arctic winter in itself breeds neither scurvy nor discontent. 2) I have shown that men may subsist in Smith Sound, independent of support from home. 3) That a self-sustaining colony may be established at Port Foulke and be made the basis of extended exploration. 4) That the exploration of this entire region is practicable from Port Foulke—having from that starting point pushed my discoveries much beyond my predecessors'—without any second party in the fields to cooperate with me, and under the most adverse circumstances. 5) That with a reasonable degree of certainty it is shown that, with a strong vessel, Smith Sound may be navigated, and the open sea reached beyond it. 6) I have shown that the open sea exists.

Hayes did not succeed in returning on a second expedition in a steamer; but in 1869 he visited Greenland in the "Panther" together with the artist Bradford; this voyage increased the knowledge of the glaciers of the Melville Bay, but was otherwise of no interest.

In 1869—70 the second German North Polar Expedition to North-east Greenland was undertaken under Capt. Koldewey and Lieut. Payer in the screw steamer "Germania" and the sailing vessel "Hansa."

In August the "Germania" made her way through the pack-ice to Sabine Island and followed the coast in a northerly direction, this part of the country being called by the name of Kong Wilhelm Land; in lat. 75½° N. the expedition turned back and went into winter quarters at Sabine Island; during the winter a sledge journey was undertaken to lat. 77° 1′ N. In the following summer a long stay was made in Franz Joseph Fiord, and during the latter half of August the "Germania" started on her voyage home, arriving in Bremen on September 11th, 1870.

The "Hansa" did not reach the shore, but drifted with the ice in a southerly direction; she was crushed in the ice and the crew, after having drifted on an ice floe for three months, eventually reached Friederichsthal by means of the two boats of the "Hansa," and arrived in Bremen ten days before the "Germania."

The result of this expedition was the mapping out of the distances traversed, scientific investigations of parts of Franz Joseph Fiord and valuable natural history collections (Die zweite deutsche Nordpolsfahrt, Leipzig 1873—74).

In 1870 Professor A. E. Nordenskiöld and Dr. S. Berggren visited Disko Island; they arrived on July 2nd, went from Disko to Egedesminde and in 68° 22′ N. lat. attempted to traverse the inland ice. Owing to untoward circumstances they only succeeded in reaching as far as 56 km; after having covered this distance they returned to Disko with a view to carry on geological researches, and in the course of these researches the large iron blocks

were found at Uivfaq. Of these blocks, which Nordenskiöld mistook for meteorites, the two largest weighed 9 and 20 tons respectively.

By the unanimous consent of the North American Senate, which received the sanction of the President on July 12th, 1870, it was determined that an expedition should be sent out under Capt. C. F. Hall with the object of reaching the North Pole. For the expedition was selected the United States' steamer, "Periwinkle" (rechristened "Polaris," a staunch tug of 387 tons burden). The members of the expedition were, besides the leader: Emil Bessels, surgeon and chief of corps; R. W. P. Bryan, astronomer; Frederick Meyer, meteorologist; Sidney O. Buddington, sailing master; George E. Tyson, assistant navigator; William Morton, second mate; Emil Schumann, chief engineer; N. I. Coffin, carpenter; a crew of 14 men and two interpreters, besides the Eskimo Joe and his wife, Hannah.

The instructions of Hall were to proceed to the west coast of Greenland for the purpose of getting dogs; then to go north from Upernivik and, from Cape Dudley Digges, to penetrate as far as possible in the direction of the North Pole with vessel, boats and sledges.

The "Polaris," which was provisioned for two and a half years, sailed from New London on July 3rd, 1871, called at Fiskernæs on the 27th and at Holsteinsborg on the 31st. Here Hall met the Swedish expedition under Baron von Otter, who reported that ice conditions were favourable, and that Hans, the dog driver from Kane's and Hayes' expeditions, was at Upernivik. Hall remained at Holsteinsborg till August 2nd, in vain awaiting the arrival of the "Congress" which was to bring him provisions from home, and then proceeded to Godhavn where, to his great relief, he was joined by the "Congress." On the 17th the "Polaris" left Godhavn, and after 33½ hours anchored at Upernivik, where Hans with his wife and three children were taken on board.

On August 24th the "Polaris" left Upernivik in a dense fog and calm, which continued until the following afternoon, when Cape York came in sight, and sails were set before a fresh breeze, but already at 7 p.m. the vessel encountered the pack, and the sails were taken in. The vessel was soon again in open water, but again encountered the ice; at 2 p.m. on the 26th she was due west of Cape Dudley Digges, distant about 13 km. Off Saunders Island large ice floes were sighted with great quantities of sleeping walruses; two were wounded, but disappeared with the rest. Not until west of Hackluyt Island did the ice become so heavy that the vessel was stopped, on the morning of the 27th, but she managed to get through and at 9 p.m. was once more in open water. After having met a few icebergs the "Polaris" at 8 p.m. lay off Rensselaer Harbour; Smith Sound was open, and the course was shaped for Cape Frazer, which the "Polaris" managed to pass by, working its way through a narrow channel, however, without any great

difficulty. The joy was great on board, when in the morning of the 28th the mountains of Grinnell Land came into view. The sailing was continued in foggy weather, the "Polaris" passing to the west of an island which did not exist on Hayes' map; at 3 p.m. the fog lifted, the country on both sides of Kennedy Channel came into view, but at 9 p. m. the fog settled once more, being now so dense that it proved necessary to make fast to a floe. At midday on the following day the fog lifted, and the position was determined at lat. 81° 20′ N. and long. 64° 34′, and thus, fog and clear weather alternating, the "Polaris" made her way through dense ice-masses until the morning of the 30th, when she was stopped by impenetrable masses of ice, in lat. 82° 26′ N. Capt. Hall was proud of the result achieved, the highest latitude hitherto reached in those parts, and hoped to penetrate still farther north.

However, it proved impossible to maintain the position gained, as a strong current carried the vessel towards the south, and after having steamed for a few kilometres towards the south, the "Polaris" at 7^{30} a. m. was secured to a large ice floe, while the drift towards the south continued with fog and dense snow. At 7^{15} p. m. the ice opened somewhat, and Hall steamed towards the south-east and arrived in the neighbourhood of a small bay which he had determined to explore, but he was prevented by the masses of ice lying outside it, and the "Polaris" was once more made fast to an ice floe. However, she soon started again, sailing about for some time in different directions. Hall made another unsuccessful attempt at reaching the small bay, which was named Repulse Harbour, but at noon on the 31st all progress was stopped by solid masses of ice.

The sailing master Capt. Buddington now urged Hall to go into winter quarters in a bay which he had observed a few kilometres south of the present position, on the plea that it was useless to expose the vessel to the peril of being crushed or losing all the ground gained. After his remarkable success Hall was unwilling to follow this advice and called a council of all the officers, who unanimously declared themselves to be of the opinion of Buddington. Hall had two alternatives before him, either to go at once into harbour on the eastern side or to try to reach the western coast. He resolved to take the latter course, strengthened in his opinion by a dark cloud in the north, which might mean open water. At 5 p. m. on August 31st the progress made only amounted to 19 km. The difficulties with the ice increased, and on September 1st the situation was so serious that all preparations were made for the abandonment of the "Polaris." In the mean time the vessel had drifted in the direction of the west coast, where, to the great joy of all, a bay appeared, which soon afterwards was reported to be covered with ice. On September 2nd the pressure of the ice became so strong that it was resolved to land everything necessary for a wintering on the ice, and from the few glimpses caught of the coast between the snow-squalls it appeared

that the vessel was rapidly drifting towards the south. On September 3rd the wind changed to the south-east, and the pressure was lessened; however, the southern current and the snow-fall continued until the 4th, when the wind calmed; the weather cleared, and the prospects improved, so that everything was taken on board, and at 9 p. m. the ice had scattered so much that the "Polaris" could head for the east coast. At that time she was 19 km south-east of the southern headland, at the entrance to the channel, from which she had drifted, and at midnight she was quite close to the coast. After Hall had been ashore in order to investigate conditions the "Polaris" anchored at 1^{30} a. m. on September 5th in a small bay sheltered by an iceberg, which was given the name of Providence Bay.

The crew immediately set to work to land a large quantity of stores and provisions, as a measure of precaution in case the vessel should be destroyed by the ice. As soon as the opportunity offered, the latitude of the harbour was determined at 81° 37′ N. its longitude being 81° 37′ N., and it was named "Thank God Harbour."

Observatories were built ashore, together with a house for the recreation of those occupied in the work; the dogs were also taken ashore, and on board the whole available space was utilized with the greatest possible economy as regards fuel.

The survey work began, including the determination of a base for the measuring of the west coast. A small bay north of the harbour was given the name of Polaris Bay.

On September 18th a hunting expedition was sent out, and after seven days' absence it returned with a musk-ox weighing 124 kg and some hares. On September 27th and 28th the "Polaris" was exposed to heavy pressure, caused by a gale from the south-east and highwater. The sheltering iceberg was moved 90 m and the vessel 45 m, but otherwise she remained undamaged.

Owing to dissatisfaction among the men Hall determined that the same kind of food should be prepared both for the officers and the crew, and after having given Buddington the command of the "Polaris" and detailed instructions for the management of the work in his absence, he left, on October 10th, on a sledge journey, accompanied by Chester, Joe and Hans, with one heavily loaded sledge and a team of 12 dogs. The object of the journey was to penetrate as far north as possible along the coast, to investigate ice conditions farther north in view of an expedition across the sound in the following spring, and to shoot musk-oxen for the winter provisions of men and animals. The following morning Hans came back for another sledge and more dogs; and the party then headed in a north-westerly direction; without special difficulties they reached Newmann Bay, on the ice of which they advanced in a north-westerly direction, making good progress; on the 17th they were making for the cape on the north side at the mouth of the bay, but at a distance of 0.8 km it proved necessary to stop, owing to open

water. Here, as everywhere, an *igloo* was constructed at once, and Hans and Joe went out to shoot seal; but as they had no kayaks, many of the animals sank. On the 18th Hall, accompanied by Chester, climbed the cape. He saw that the east coast here ran towards the north-east and then north; the country on the west side of the channel ran in a north-east direction, until it appeared to end in a cape, almost due north. On the following day Hall went round the cape, but could not proceed, as the coast became too steep. The northern headland was named Cape Brevoort, the southern Summer Headland. The latitude was determined at 82° 00′ 30″ N.; a cairn was erected with a report, and botanical specimens were collected.

After the party had been detained for some days by a violent storm, they started, on the 24th, on their home journey, as Hall had not sufficient strength to continue, and on the same evening they reached the last station but one, or, as it was called, the 5th camp. On the 24th the expedition was back at the "Polaris."

On his return Hall found the preparations for the winter in full train. He was in good spirits, but the last few days he had been very unwell, and as his condition rapidly grew worse, Dr. Bessels was called from the observatory; he declared that Hall had been seized by an apoplectic fit, and in spite of apparent rallies he died in November 8th, to the despair of all on board. He was buried on the 10th, and thus a long life, spent in Arctic endeavour and enterprise, was brought to an end.

During the two weeks of Hall's illness the crew had been engaged in banking up the sides of the ship, a wall of snow being built all about it. On land two snow huts were constructed for magnetical observations, and a small shed was built on the east side of the observatory for meteorological observations. On the 3rd 13 dogs had died, but 56 Newfoundland and 48 Eskimo dogs were still left. The sun had been seen for the last time on October 16th, and the daylight decreased steadily, so that stars of the first magnitude could be discerned at noon.

On the death of Hall the command passed to Buddington, who conscientiously followed the arrangements made by his dead leader as regards the daily routine and the life on board.

On the 18th a gale sprang up, which soon acquired an hourly velocity of 75 km, and it continued with undiminished force until the 20th, the temperature at the same time falling to —29° C. On the 19th the "Polaris" was thrown over on one side and the surrounding snow wall broken down. At 1 a.m. of the 21st the "Polaris" began to feel the motion of the open water; at 2^{30} a severe shock occurred, and she was afloat, constantly colliding with the ice floes; at 8 a.m. the ice broke up and was carried away, and the starboard anchor was let go, but did not take the chain; the vessel had been brought up against the iceberg and was prevented from being carried into the pack. She was immediately secured to the iceberg, and the shocks

sustained were terrific, but the hawsers of the ice anchors held, and at 2 p. m. the gale moderated. The water in the harbour was still in violent motion, so that it could not freeze, but on the 23rd the gale was entirely spent, and at once ice began to form. The stern of the "Polaris" was not sheltered by the iceberg and was greatly exposed to the attack of the ice-floes from without, and so at a distance of 15 m from the iceberg a dock was sawed in the young ice, already 17 cm thick, and in this dock the ship was lodged. On shore the observatories had suffered a good deal from the gale, but the instruments were undamaged.

On the 28th, in the morning, a light breeze sprang up from the south, which at about 7 p. m. had risen to a gale, carrying away huge quantities of ice from the sound against the iceberg: the latter was unable to stand the pressure, but split up into two parts, the smaller of these drifting against the ship, while at the same time a large tongue of ice was forced under the bows of the vessel and gave her a cant, and the iceberg drifted towards the shore, pushing the "Polaris" before it. At 2 a. m. the tide turned, and being on the ebb the iceberg took the ground so that the danger was past for the present. No great harm had been done, but after these events the Eskimos asked for permission to live ashore, where they built two snow huts.

The month of December passed without important events; the "Polaris" continued in the same position, leaning against the iceberg and her bow perched upon its tongue. The iceberg was steadily growing smaller, piece by piece falling off it, and it pressed more and more against the vessel, thus increasing the angle of declivity. Owing to the absence of the snow wall round the vessel the cold drove people away from the bunks along the side of the ship, but, in spite of everything, Christmas was celebrated with great festivity and gaiety, only damped by the shadow which had fallen upon the expedition by the death of Hall.

The preparations had already begun for the sledge journeys to be undertaken in the course of the spring, and Hannah was busily engaged in sewing skin clothes. On January 2nd pendulum observations were commenced, the ship's engine was examined, cleaned and declared to be in excellent order, but attempts at loosening the ice under the vessel by means of gunpowder proved futile. The highest temperature in the course of this month was —16° C., the lowest —30° C. Glorious auroræ boreales were observed.

In February the highest temperature registered was —12°, the lowest —42° C., and on the 28th the sun was above the horizon until 2 p. m.

During the early half of March there were strong gales, and owing to the constant movement of the "Polaris" during these storms the cradle of ice, in which she lay, constantly increased in thickness by additions to its surface. Thus the ship was lifted bodily, and the two metre mark became visible. The higher the "Polaris" was lifted, the greater was her inclination at low tide, all this being a severe strain on the ship, the timber of which

gave way; while the engine was proved to have shifted 7 cm to the port side. On the 23rd Hans shot a seal and later on a hare, and the animal life generally began to revive, especially as far as the birds were concerned. On one of his hunting expeditions towards the south Joe saw a fiord, which was named after Petermann. When the weather was fine, there was constant traffic in the neighbourhood of the vessel, and whatever was found of interest was delivered to Dr. Bessels, who himself took a very active part in all scientific work.

On the 27th Bessels, accompanied by Bryan and Joe, with a team of 14 dogs, set out in the direction of Cape Constitution, the object being to survey the intermediate distance. Besides, preparations were made for two other boat expeditions. The one boat was called "U. S. Grant," the other "George M. Robeson," or for short No. 1 and No. 2, under the command of Chester and Tyson respectively; Frederik Meyer, the scientist, with four of the crew, was going with No. 1 while Bessels, also with a party of four, was going with No. 2. These boats were to be ready on May 1st. On April 1st at 8^{30} p. m. the sun appeared above the mountains of Grinnell Land, and it would soon be above the horizon throughout the twenty-four hours.

On the 8th in the morning Bessels returned with his party, all being well except the doctor himself, who was suffering from snow blindness. Their first camp had been Offley Island where they made a snow hut, in which they managed to get a temperature of + 13° C. On March 28th they entered Petermann Fiord, but already on the 29th they were stopped by an unsurmountable ice barrier. Another snow hut was constructed in lat. 81° 05′ N. On the 30th the party returned to Offley Island, from where, on the following day, they started towards the south. At the start the sledge broke down, and Bryan and Joe returned to the ship to fetch another sledge, Bessels awaiting their return alone with the dogs. On the 2nd in the afternoon the whole party started again towards the south; they passed Petermann Fiord and shortly afterwards a narrow fiord (Bessels Bay) and Cape Morton, where they saw the first signs of an ice foot, and after a very strenuous journey they reached Hannah Island, where they camped. On the following day Bryan took observations, obtaining a latitude of 81° 07′, and the high mountain (Cape Bryan) was found to be 362 m high. On the 5th ice conditions had become so much worse that they resolved not to proceed any farther, but confined themselves to identifying Cape Constitution at a distance of 42 km. On his return to the ship Bessels, as already mentioned, suffered from snow blindness and was obliged to keep his bed. Not until the 24th could he once more take up his work at the observatories.

On the 22nd open water was observed to extend from coast to coast. On the 25th Joe and Hans returned from a hunting trip to the north of Newmann Bay, where they had killed seven musk-oxen, one hare and two ptarmigans. The crew had for some time been employed in clearing the deck

of the vessel of ice and snow and overhauling the rigging. The rudder and propeller were found to be in good order, though the log says that "it may prove difficult to keep the 'Polaris' afloat, as she has suffered so much from the pressure of the ice." Towards the end of the month several hunting trips were made with good results, while at the same time the survey of the coast was undertaken as far as Cape Lupton. The highest temperature registered for April was $-9°$ C. the lowest $-34°$ C.

From the 24th the vessel began to leak, and an attempt was made to pump it out. A tent was arranged on deck for the Eskimos, eight persons in all, the filth accumulating in their quarters, which was perfectly indescribable, having given offence to their neighbours. The highest temperature registered in the month of May was $-\frac{1}{2}°$ C. the lowest $-20°$ C. At times the sound was seen to be full of pack ice.

On June 1st the boats No. 1 and No. 2 were ready to start, but the ice was unfavourable, and the crew growing impatient, Buddington sent them out on a hunting expedition, while Tyson went north to scale a height with a view to investigate ice conditions in the sound, but on his return he was only able to report that it was full of ice. On the 3rd the leak of the vessel was found; it was on the starboard side of the bow, right below the 2 m mark, but in the course of the efforts made to stop it, a similar leak was discovered on the port side, which unfortunately was under water at low tide and so could not be stopped, while the whole stern was wrenched and split.

Finally, on the 8th, it became possible to start on the boat expedition, for which preparations had gone on for so long. Chester started first with No. 1, shaping his course for Cape Lupton, and on the same day No. 2 set out, also for Cape Lupton, while Tyson and Bessels remained on board. However, already on the 9th, Chester returned with the melancholy intelligence that his boat had been crushed by the ice; the men were all saved, but among the articles lost was the Casella theodolite of the expedition. Chester earnestly begged to be permitted to make another attempt in the portable folding canvas boat, the rigging out of which began at once. In those days a small pumping machine was worked six hours out of the twenty-four to keep the vessel free from water.

On the 11th Hans was sent to Cape Lupton, communicating on his return that Tyson had started, and on the 12th Chester set out in the canvas boat. On the 19th the vessel was leaking worse than ever, so that it became necessary to work the pump for twelve hours instead of six. On the 21st and 22nd there was a gale from the north-east; the ice broke loose up to 9 m from the vessel, so all instruments were transported on board, and everything about the observatories that could be used for fuel was taken to the vessel. The ice around it was 3 m thick, and all attempts to burst it with gunpowder failed, so the engineer set about making ice saws for the

cutting out of the vessel. On the 26th the "Polaris" was once more afloat, but leaking so badly that the steam pump was at work all day without cessation. Everything of any value was taken on board, and Buddington resolved to start at once under sail for the north, as ice conditions seemed favourable, and at the same time it was thought that the party on board might be of service to the boats. It proved impossible to get both of the anchors; the one which lay under the iceberg was inaccessible, but the other lay clear, and the "Polaris" reached open water at Cape Lupton, but here she encountered impenetrable pack-ice, and on the following morning she returned to Thank-God Harbour and tied up to her old friend Providence Berg.

On the 22nd two of Chester's crew returned with a note from him asking for some bread. They reported that both parties were encamped to the north of Newmann Bay and that it was impossible to proceed. Buddington resolved to fetch the boats, not only in order to secure the service of the men on board the vessel, but to be ready to move north in the vessel, should opportunity offer.

In the afternoon the "Polaris" got under way, but was unable to penetrate beyond Cape Summer. Hans was sent ashore with instructions to Chester to return with the boats, while the "Polaris" went back to the harbour where she succeeded in obtaining one anchor.

At the beginning of July Buddington made another effort to reach Newmann Bay, but once more encountered the pack of Cape Summer; then he ran south-west down the face of the pack, but throughout its whole extent, as far as Cape Cracraft, there was no opening for a boat. The two messengers from the boats were landed at Cape Lupton with letter and some supplies to Chester, and the "Polaris" once more returned to the harbour, which it was forced to leave for a short time, on the 9th, when the land ice broke loose. On the following morning a gale from the north-east filled the harbour with heavy ice floes, which the crew kept off, but only by straining their power to the utmost. The following days, until the 29th, were a constant fight against the ice, which was pressed into the harbour, frequently attended by severe snow squalls. During the latter half of the month the boat crews returned to the vessel, after having lost their boats and some material along the shore.

Every day, the last being on August 1st, people were sent up to the greatest height, with the object of investigating the state of the ice, but they all returned with the depressing intelligence that the sound was full of pack ice. A careful estimate was made of the quantity of coal at hand, and it was realized that there was only enough for six days' steaming, which, under favourable conditions, would be sufficient to take the "Polaris" to Disko.

Until August 6th the vessel was exposed to the attack of ice-floes, which

drifted into the harbour on the 5th in such enormous quantities that the ship was set ashore, though she was afloat again at next highwater. On the 11th the ice of the sound was observed to be in motion, drifting to the south; after having examined conditions Buddington determined to try to force the vessel through in a southern direction, and all preparations were made, including the leaving of a supply of provisions ashore for a future emergency. On the 12th the wife of Hans gave birth to a son, and on the same day at 4^{30} p. m. the "Polaris" left the harbour and, after much wrestling with the ice, reached open water at 5 the following morning. However, already at 9 a. m., an impenetrable ice barrier was encountered; the vessel was tied to a large ice floe and in the following days drifted with the pack, twice receiving nips which made her heel over, and from the 27th everything was made ready to abandon the ship.

In September the "Polaris" continued drifting south, but with an almost negligible speed and without severe gales which might have spread the pack. The preparations for leaving the ship were still going on by placing as much as possible on the deck: the gaff-top-sail and the storm-stay-sail were unbent and cut up into bags for coal and bread, and two tons of coal were brought on deck in bags. The Eskimos were calculated to be able to provide the necessary quantity of seals for the winter supply of blubber. On the 16th a house was begun on the floe to which the vessel was made fast, and which was about 4.2 m in circumference. The leak was the chief cause of anxiety, as 450 kg of coal a day were required for pumping, and all efforts at stopping it failed. An attempt was made with a small auxiliary engine, which reduced the consumption of coal by 225 kg. Hans killed many seals, some of which were eaten, while others were put by for the winter, and Meyer who had begun to show signs of scurvy was cured by means of seal blood and raw meat. It had for some time been necessary to have lamps about the ship, and on the 27th artificial light was required from 8 p. m. to 4. a. m. for the reading of the instruments.

On October 1st the latitude was 79° 0′ N., while the minimum temperature at night was −18° C. The "Polaris" still drifted south, and on the 4th Rensselaer Harbour was thought to be 32 km distant. The seal hunting proceeded favourably, and on the 8th the house on the floe was finished; the leak became smaller, and it was hoped that the frost would stop it entirely. On the same day Cairn Point was sighted to the south-east, 3.2 km distant. A gale from the north-east which sprang up on the 11th greatly accelerated the southern drift, changed on the 15th to the south-west, and further measures were taken for abandoning the vessel. At 7^{30} p. m. the "Polaris" received her severest nip, and one of the firemen came hurrying on deck, reporting that a piece of ice had been driven through the sides; Buddington ordered provisions and stores to be thrown on the ice, together with the boxes containing note books, observations, etc. and finally two boats. The very floe cracked,

and all endeavours were concentrated on collecting as much as possible. The hawsers which had held the "Polaris" slipped, and the vessel was carried away. Fourteen men had remained on board, *viz.* Buddington, the mates, Chester and Morton, Dr. Bessels, Bryan, the engineers, Schumann and Obel, the carpenter Coffin, two firemen and four sailors. The vessel was drifting rapidly, as by a miracle clearing two icebergs, and at the very last moment, before the water rose to the fire plates, a successful attempt was made at setting the steam pump going; the tired men at the hand pumps were relieved, and the steam pump steadily gained on the leak. At midnight the drift of ice stopped, and the storm abated; it was a terrible night; all bedding had been removed to the floe, with only a few blankets left, and the crew had no other clothes than those on their backs. In the following morning it was observed that the vessel was right between Littleton Island and Cairn Point, and only 8 km from the coast. To the grief of all it was impossible to see any trace of those who had been left behind on the ice.

The joy was great when the propeller was made to revolve slowly, and the rudder, though damaged, could still be relied upon to a certain extent. A light breeze sprang up from the north-east; sails were set, and an attempt was made to get the ship nearer the shore. The attempt proved successful, the "Polaris" taking the ground about 360 m from the shore, and on the 18th the hard work at landing everything was begun. On the 19th in the morning the sound of dogs was heard, but the hope that it might be the party from which they had become separated, was frustrated. The new-comers were two Eskimos with nine dogs, and they were greatly surprised at seeing the great number of seals and musk-oxen hanging in the rigging. The building of a house was begun at once, but as there was no material for a roof, they had to content themselves with canvas. The Eskimos helped with their sledges to transport the contents of the vessel to the shore, and so did six other Eskimos, who turned up on the 21st, and left for home on the 24th with many presents. The coal supply was now reduced to 6 tons, but the vessel could supply much timber for fuel. On the 24th the pumps were stopped, and on the 26th the water had risen within 0.9 m of the upper deck.

During the remainder of the month the vessel was visited by Eskimos from Etah. The hunting on an average yielded good results. Chester, Bessels and Noah Hayes set out to find the boat left by Dr. Hayes at McGary Island, but without result.

On November 1st the meteorological observations were recommenced, and a small house was built for the transit instrument. Two Eskimo families from Etah made their appearance, having been driven from their homes by want of food, and upon the whole there was a constant coming and going of Eskimos, the only break in the otherwise monotonous daily life in the "Polaris" household. Coffee gave out, and rye was used instead, while

the many foxes, which had hitherto been given to the Eskimos, were now reserved for the members of the expedition.

On January 11th a party of eight men, two women and one child, and drawn by forty to fifty dogs, arrived from Northumberland Island, among them several who had known Kane and recognized Morton. After the middle of the month the supply of coal gave out entirely, and as all the wood to be found near the house was soon used up, it was necessary to go over the ship, where great care was observed to leave untouched the parts from which the boats were to be taken. About that time the Eskimos had left the "Polaris" house in order to seek more southerly hunting grounds; only Jim and his wife Evallu remained, the latter being of very great service in the sewing of skin clothes. On February 20th two Eskimos brought a great supply of walrus meat, which was extremely welcome, as symptoms of scurvy had begun to show among the party. On the 27th the sun appeared, and the highest temperature registered was —17° C., the lowest —45° C.

The Eskimos still came and went, the total number of guests about March 4th amounting to 51 individuals, and on the 8th eight more arrived with walrus meat, most of them, however, intending to go out bear hunting.

On April 10th Bessels set out together with two followers and two sledges containing the necessary instruments and provisions for six weeks, their object being to reach Humboldt Glacier and possibly also to cross Smith Sound. He returned on the 18th on account of difficulties with his drivers. Having attained a latitude of 79° 16′ N. he encountered a quantity of high ice floes which the natives refused to cross, and then he headed for the west coast which he reached at a point right between Henry and Bache Islands. Here he again encountered heavy ice floes, which the natives refused to tackle, and then he went south along the coast, as far as the mouth of Baird Inlet, from where he resolved to return, his Eskimos, as already mentioned, beginning to give trouble. Before he headed for the "Polaris," he was compelled to retrace his steps to Rensselaer Harbour, in a violent snow storm, so as to get around the open water again.

On the 19th Bessels started south to find an Eskimo to go with him, and also to obtain some more food for the dogs, walrus skin with some of the blubber remaining on it. After having secured the Eskimo as well as the dog food Bessels, on the 22nd, once more started north with Jim and two sledges; however, he was obliged to turn back the same day, as the one sledge had broken down off Cape Inglefield. When the sledge was taken to be repaired, it turned out that the Eskimo who accompanied him had done it on purpose, as he was determined not to make the journey, and Bessels sought and obtained permission to undertake the journey only attended by Hobby, one of the remaining crew. The season was now too far advanced to carry through his original plan of heading north from Thank-God-Harbour, and so it had to be abandoned. On the 28th there

was open water within 230 m of the coast, and farther north it seemed to touch it.

Up to May 1st there had been one hundred and two Eskimos, men, women and children, at the "Polaris" house, with as many as a hundred and fifty dogs, the greater part living along the coast from Humboldt Glacier to Melville Bay. The members of the expedition frequently returned these visits in connection with hunting expeditions; thus Hayes and Campbell spent a few days with the Eskimos at Etah-Watanny where they were present at a funeral and a divorce, both attended by very peculiar ceremonies. On the 13th Bryan, accompanied by Jim, started for Rensselaer Harbour, with the object of determining the difference of longitude between this and the "Polaris" house. Game now was abundant, especially seals, hares and birds. On the 27th the boats were finished; they were 7.5 m long, 1.5 m broad, and 0.8 m in depth, their planning being due to Chester, who had shown great skill and ingenuity in their construction. Bessels had been away at Foulke Harbour to determine the meridian difference between that locality and the "Polaris" house, and on his return he passed the grave of Sontag which had been despoiled by the Eskimos; the granite stone was gone, and his bones were scattered about. Bessels buried the cranium and the other bones found.

The 29th was fully occupied in active preparations for the departure of the party, each one being allowed to take 4 kg only, while provisions for two and a half months were carefully packed in small bags. On the 30th the land ice was almost entirely gone, and the "Polaris" went adrift, but grounded again about 130 m farther south. On June 2nd the library of Hall was packed in a trunk, which was placed in a depot, 4 m E. S. E. from the house, together with the pendulum, the transit instrument, three box-chronometers and a report of the course of the expedition and their project of trying to reach a whaler at Cape York or the Danish settlements.

At 2^{30} on the 3rd the boats got underway, one being commanded by Buddington and the other by Chester. They stood down the coast, doubling Cape Alexander at 6 p. m. but at 11 p. m. they were stopped by the ice and had to return to Sarfalik, where they were hauled up on the ice foot. On the 4th at 6 a. m., they were launched once more and continued along the land ice, and after rowing for fifteen hours they reached Hackluyt Island. A gale with a violent snow storm detained them there for a couple of days, and not until the 8th were they able to set off once more, reaching Northumberland Island at 11. a m. After various unsuccessful attempts at proceeding the boats were again hauled up on the ice foot, and Chester climbed a height, and returned with the welcome intelligence of good prospects for reaching Cape Parry. Another attempt was made, but at first without success and so, with varying luck, they continued their endless fight against the ice, until on the night of the 23rd, in the neighbourhood of Conical

Rock, the tired crews who had lain down for a few hours rest were roused by the watchman calling out: "Ship ahoy!"

Three masts and the smoke stack of a bark were quite visible, and the joy was indescribable. The flag was hoisted on two oars lashed together, and they soon received notice that this signal had been seen. Chester and Hobley were dispatched at once to communicate with the vessel, but half-way they were met by the men. Two of them turned back to report to the captain, the others continued with Chester to the boat, having been so thoughtful as to fill their pockets with ship's biscuits, as they thought the men might be actually starving. They brought the joyful tiding that Capt. Tyson and his men were saved; after dreadful sufferings they had, on April, 30th, been taken on board the steamer "Tigress," in lat. 53° 35′ N. of Grady Harbour, Labrador.

At 6 p. m. on the same day, after partaking of a hearty meal, they all prepared to walk to the vessel, kindly assisted by their new companions; each man carrying his personal effects and collections. At midnight they reached the "Ravenscraig," which lay in lat. 75° 38′ N., long. 65° 35′ W., where they were most kindly received. On the 25th twenty men of the crew of the "Ravenscraig" returned with two of the men from the "Polaris", in order to fetch what had been left of any value in the neighbourhood of the house. On the 26th the "Ravenscraig" set out in a westerly direction, on August 6th reaching Lancaster Sound, where she met the steamer "Arctic." Owing to the overcrowded state of the "Ravenscraig" eight of the "Polaris" men now went on board this vessel, and in these two vessels the expedition reached America in safety.

The highest latitude reached by the "Polaris" Expedition was 82° 16 N., the west coast of Greenland having been mapped as far as this point, and corrections made in the coast lines drawn by Dr. Kane and Dr. Hayes. Further astronomical determinations as well as meteorological and magnetical observations had been undertaken according to a definite plan, while valuable zoological and botanical collections had been made.

In 1871 geological investigations were undertaken in Disko Island by Dr. K. J. V. Steenstrup, who had been a member of the Swedish expedition which brought back the above-mentioned iron block from Uivfaq, and in 1872 and 1874 he continued his researches, in the latter year together with Professor Johnstrup (Videnskabelige Meddelelser fra Naturhist. Foren., København, 1874, 1875).

In the summer of 1875 the Norwegian geologist A. Helland, during a stay in northern Greenland, made a series of observations of glaciers and ice-fiords in that locality (Archiv for Mathematik og Naturvidenskab, Christiania, 1872). During the same year Disko was visited by the Frenchman Charles Rabot, and also by the Swede Dr. Fries, accompanied by two naturalists, the three latter spending the winter in Disko.

One of the tasks which had been set the English Polar Expedition under Capt. G. S. Nares was to investigate the north-west coast of Greenland from Repulse Harbour and as far towards the east as conditions permitted. Instructions in accordance with this programme were given to Lieut. Beaumont, as the leader of the expedition, these instructions further presupposing land to the north of Greenland, which land should be investigated by means of the two sledges placed at the disposal of the party.

On April 24th, 1876, Lieut. Beaumont who had been detailed for this work, left the "Alert," one of the two vessels of the expedition which at that time was stationed at some distance north of Black Cape. The sledge expedition had provisions for 56 days, and, besides the leader, it consisted of Lieut. Rawson, Dr. Cappinger, the chief boatswain's mate, George Emmerson, and a crew of 34 men; further, there were two sledges "Sir Edward Parry" and the "Discovery," with two auxiliary sledges, the "Stephenson" and the "Alert."

Black Cape was reached without any difficulty, and from there the course was shaped for Repulse Harbour. The passage across the sound was difficult, owing to the frequently very tall ice floes, particularly in the neighbourhood of Repulse Harbour. Here a cache was laid out for the home journey; the remaining provisions were divided among the three sledges, while the fourth, commanded by Emmerson, was sent back to the "Alert" with a report of the course of the journey.

On April 27th Beaumont set out, and on the following day he arrived at the farthest point reached by Rawson during a reconnoitring trip a few days previously, from which he had brought back intelligence of favourable conditions. If he had gone 9 km farther, the report would have been different, for here the sledge party encountered a layer of snow, so deep that only by unloading the sledges could they bring them forward.

The coast began to recede towards the north-east, forming a very steep slope of snow, along which the sledges were taken with great difficulty, sometimes one at a time by the whole of the crew; that Beaumont did not follow the ice, but the coast, was because he feared to pass, unobserved, obstacles which might prove unsurmountable on the return journey if the ice broke off. After the first day the coast presented a wall of perpendicular rocks, and Beaumont ventured to trust that the ice would remain; 6 km towards the east conditions, however, changed, and here again they encountered the steep snow slope, the inclination of which in some places amounted to 20°, and they plodded laboriously on, passing a very peculiar row of cliffs, called by the name of Black Horn Cliffs. On May 4th they reached a place which seemed well fitted for a cache, and here rations were deposited for 12 men for a period of 10 days; and from here Dr. Cappinger returned with the third sledge. This journey over sloping ground was very fatiguing for the men and bad for the sledges, as all the time most of the

weight was on one runner. On May 5th, off Cape Stanton, prospects became a little brighter, as the route here passed across a broad inlet. On May 6th one of the party, I. I. Hand, first complained of stiffness in legs and increasing pain. On the following day they again passed an inlet, the level ice surface of which did not seem to have changed for many years; this inlet was named Frankfield Bay. The coast which had hitherto been high, now became low, with a remote background of mountains. Travelling, which in the last few days had been easy, now again became difficult, with high snow drifts, so that it proved necessary to give the men a day's rest. It soon turned out that Hand was suffering from scurvy, and Beaumont resolved to make a halt until the 10th, in the hope that he might recover; however, his condition grew rapidly worse, and on the 11th Beaumont resolved to send Rawson back with him to Repulse Bay. On the same day Beaumont and the remainder of the party proceeded; the going was fairly good, and they reached a point where the trend of the coast, which had hitherto been north-easterly, changed to the east, but an overcast sky prevented their obtaining a meridian of this point, up till now their most extreme north, which was named Cape Bryan. A cache was made, whereupon they started for Cape Fulford, the extreme point on the western side of St. George Fiord. As Beaumont was now alone and considered it more important to explore the coast, he thought he would leave off following his instructions to investigate what appeared like deep fiords, and so he passed right across St. George Fiord, where travelling was easy, and headed straight for Dragon Point. From here Beaumont sighted a number of bays and inlets, but he did not think that he would be able to explore them single-handed and headed for Cape Cleveland. Until May 16th the travelling had been good, and they had made fair progress, but in the evening they encountered soft snow, about 45 cm deep, which was a great disappointment, as the distance to Cape Butress was a level plane, which they had hoped to traverse without any difficulty. The going became harder and harder, in snow which was deep and of the consistency of wet sugar, and Jenkins, Craig and Paul complained of stiffness in the legs. The following day it was bright sunshine; they all suffered from a burning thirst and were obliged to stop every 50 m to get their breath. Beaumont walked ahead, at a distance of 3 km, in order to investigate whether the going was better below the cliffs of the shore, but at last he sat down exhausted and then returned to the sledges, realizing the impossibility of their being able to overtake him. The men had, however, done their best to pull the sledges, crawling on hands and knees to protect their aching legs. The progress made in the course of the day only amounted to 3 km, and Jakes was stiff-legged. In spite of their desperate plight they continued, on the 19th, in the direction of Cape Hooker, as the coast only seemed 1.6 km distant, but after they had marched for five hours, they had not yet reached it. Beaumont and Gray then continued alone for two hours and saw that

the going along the shore was much worse, as there were large cracks in the ice filled with water, and after wandering for nine and a half hours they reached the sledges where they found Craig and Jenkins down with scurvy. Beaumont resolved to wait for two days in the hope of being able to climb a height and so obtain a view of the more distant coast and islands, but this was prevented by a heavy snowfall on May 21st and 22nd. The reduced provisions forced them to abandon the hope of reaching Cape Hooker and to set out on their journey back.

While this was going on, Rawson was on his way back to Polaris Bay. Immediately after he had separated from Beaumont, two of his men had broken down, leaving only Rawson and Rainer to pull the sledge, and not until June 3rd did they reach Polaris Bay, after a painful journey with reduced rations. Rawson had been snow-blind for several days, but had, nevertheless, managed to pull the sledge. Hand died a few days after their arrival in Polaris Bay, and Bryan was very ill, though he had refused to ride on the sledge for fear of endangering the lives of the others by the delay.

Four days after their arrival Lieut. Fulford and Dr. Cappinger arrived with Hans and a dog sledge; they had been out to explore Petermann Fiord, and the sick people now received medical treatment. On June 22nd Rawson, Cappinger and Hans went to meet Beaumont.

The latter had started on the morning of the 22nd with two men at the drag-lines, he and Gray being the only ones in good condition. They followed their old track, which helped them to travel three times as quickly as on their way out, and so they reached their camps from the 13th and the 24th in two days. They arrived in the latter place in bright sunshine, Mount Hooker being visible at a distance of 20 km from the camp. They resolved to make one more attempt, Craig and Jenkins remaining at the camp, while the others prepared to set out on the following day with provisions and luggage.

However, the following morning they were forced to abandon the trip, owing to a heavy snow storm, and the whole party continued as far as Dragon Point, when the weather once more cleared; here they built a cairn, depositing a report and a map, and then Beaumont and Gray ascended a 1100 m high mountain. The view from here was so wide that it would take a whole day to make a sketch; so Beaumont contented himself with measuring angles all around the horizon and then hurried down at the sight of threatening clouds. In a severe snow storm, which lasted for five days, they reached the camp, continued as far as Cape Bryan and camped at the cache. The fallen snow had rotted the underlying crust, which gave way under the sledge and made progress difficult.

On May 28th it proved that the party had not sufficient strength to drag the full load, and a cache was made of provisions and other goods amounting to 100 kg. The snow storm continued until June 3rd; Paul and Jenkins could not keep pace with the others, and frequent halts became necessary

in order not to leave them too far behind. The legs of Dobbing and Jones became stiffer and stiffer, but they kept on pulling to the best of their ability. Beaumont and Gray were the only ones who showed no symptoms of scurvy. The sick hardly ate and could neither sleep nor rest.

Shortly after leaving this camp, Paul became entirely lame and had to be placed on the sledge, and on June 7th Jenkins followed suit. The road must be covered twice, once to bring provisions and luggage, and the second time to fetch the sick.

On the 10th Repulse Harbour was reached, and because of the sick Beaumont resolved to go across the sound to the "Alert." Leaving everything that could possibly be dispensed with, they set out on the ice, but after wandering 1½ km, they were stopped by open water, and Beaumont now saw no other prospect than of heading for Polaris Bay, which was 60 km distant. The most necessary of what had not been left behind was placed on the sledge, which there was only one to pull, Craig and Dobbing being now no longer able to do their share of the work.

On June 21st camp was pitched at a distance of 16 km from Polaris Bay, in a snow storm so violent that the tent could not stand, and the sick were obliged to lie on the sledge, barely protected from the cold. However, in the afternoon they succeeded in raising the tent, and on the 22nd at 9^{30} a. m. the party set off once more, the sick having great difficulty in breathing. On the 23rd it also became necessary to carry Craig and Dobbing; this necessitated three turns, and the distance covered was only 1½ km. On the 24th their plight was so bad that Beaumont thought of going to Polaris Bay alone on the chance of getting help, but on the very moment when he was on the point of starting, Rawson, Dr. Cappinger and three men arrived with a sledge and provisions. On the 25th Newmann Bay was reached, the sick being all the time under the care of Dr. Cappinger. In the evening they were 19 km from the cache, thanks to the efficient driving of Hans, but Paul and Jenkins were in a critical state, particularly the former, for which reason Hans and Cappinger drove straight on to Polaris Bay, while Craig and Dobbing were placed on the sledge, drawn by Beaumont and Rawson, and Jones and Gray, who were still able to walk, followed behind. The following morning the sledge came back from Polaris Bay with a letter from Cappinger telling that Paul was dead, and the next day all were back at Polaris Bay. From there the two parties, after having recovered somewhat, were taken to Discovery Harbour, where the "Alert" was now stationed.

The hitherto unexplored coast from Repulse Harbour to lat. 82° 20′ N. and long. 51° W. had now been traversed.

As a link in the chain of stations for meteorological-magnetical observations — an international enterprise which was undertaken at the suggestion of the Austrian naval officer, Lieut. Weyprecht — an expedition to Greenland was sent out from Denmark in 1882. The leader of this expedition

was Adam Poulsen (afterwards director of the Meteorological Institute of Copenhagen) and the other members were: L. Petersen, mathematician, Lieut. (afterwards Captain) C. H. Ryder, R.N., N. Hastrup, physician, C. Petersen, engineer and T. Nærgaard, mechanist.

According to the original plan the station was to be established at Upernivik, but this decision was altered, and in the end Godthaab was chosen. The expedition arrived at this settlement about the middle of June 1882, and on August 1st the observations were begun and continued until August 31st, 1883.

The observations comprised hourly meteorological observations, observations of the auroræ, measurings of water levels, etc. as well as on the first and fifteenth of every month, the reading of the instruments marking the magnetical variations, in accordance with the internationally accepted programme.

The results of the expedition were made known in the work published by the Meteorological Institute ("Exploration Internationale des Regions Arctiques, 1882—83. Expédition Danoise. Copenhague 1893,") as well as in several minor treatises by Adam Poulsen.

One of the most important tasks of the Lady Franklin Bay Expedition was, under the leadership of Lieut. Greely, to investigate the north coast of Greenland from Newmann Bay and as far north as possible, and for the carrying out of this part of the programme Greely appointed Lieut. Lockwood.

On April 4th 1882, Sergeant Brainard started from Cape Beechy with four Hudson Bay sledges, crossed Robeson Channel, and reached the coast of Greenland on the 7th. The journey took place in a temperature falling to —44° C., and already from Robeson Channel two men had to be sent back owing to serious frost-bite. On April 15th Lockwood joined the expedition with a dog sledge, driven by the Greenlander Christiansen, and on April 16th the expedition succeeded in crossing Newmann Bay; by a mistake a start was made from here up through a ravine, situated at some distance south of Cape Brevoort, which made the journey overland considerably longer. On April 22nd the whole party camped, in a violent gale, off Repulse Harbour, and from there the journey progressed along a tolerably good ice-foot as far as Black Horn Cliffs. The latter were passed on fairly good new ice, on April 24th, but, as on the preceding days, it was necessary to make the journey twice, *viz.* by advancing with half loads. On the following day the party found Beaumont's cache at Stanton Gorge, and on the following day they passed Hand Bay and camped near Frankfield Bay. The weather, which had hitherto been stormy now became fair, and in the evening of the 27th the party reached Cape Bryan, travelling taking place along an ice foot "sometimes good and sometimes bad, never very bad." Here a cairn was erected with a report, and a depot was made, consisting of all that could

possibly be dispensed with, while the four Hudson Bay sledges, which were utterly unserviceable for further progress, were sent back to Fort Conger, and Lockwood, Brainard and Christiansen continued towards Cape May. The snow was hard, but became softer off Dragon Point, where they camped on April 30th in order to rest the dogs. The sledge was so heavy that it became necessary once more to advance with half loads.

Owing to the deep snow travelling was slow, but already on May 2nd conditions grew better, though the ice had a good many cracks which, however, were passed without any difficulty, and the weather was mild. On May 3rd depths were taken with a line of 250 m, but without touching bottom, and the soundings ended in the loss of the line. The snow became harder, so that it was possible to advance with full loads.

On May 4th, in the evening, Cape Britannia was reached. Here Lockwood built a cairn, deposited rations for five days and dog food for three days and undertook observations; on the following day a high mountain behind Cape Britannia was climbed, the height being estimated at 594 m; on the same occasion it was observed that Cape Britannia was an island, and that three large fiords extended towards the south, *viz.* Nares Inlet, Victoria Inlet and Nordenskiöld Inlet. Towards the west and east, with the exception of Beaumont Island, only ice was visible. The temperature, which in the night had been —16° C. was now —9.7 C. On the summit of the Cape a cairn was erected and a report deposited. Here, as at the preceding camps, a few ptarmigans were shot, and traces of foxes and hares were discovered. In the evening the party set out for Cape Frederick, which was rounded on the firm ice. The whole of the coast towards the south was a succession of lofty peaks, with an occasional glacier.

They frequently heard the grinding noise of moving ice, and at the edge of the solid ice they saw in several places open water, but no seals. Lockwood describes Nordenskiöld Inlet as an extremely long fiord, continuing beyond the range of vision in a southerly direction. Further, he mentions a fiord, running parallel with the route travelled towards the east, by means of which the countries passed became islands. Off Ellison Island a short stay was made, and off Snow Island it was observed that "a narrow fiord seems to separate this island from the land east." At Black Cape the ice became very hummocky, indicating great pressure. At midnight on May 6th Cape Benét was reached. The weather was calm, with a heavy snow fall, and a cairn was erected at Cape Benét and three days' ration deposited. Many traces of hares, foxes and lemmings were observed.

On the following day the weather improved somewhat, and they progressed over very hard hummocky ice, passing Mascart Inlet, Jewell Inlet, Pocket Bay and Cape Malm in deep snow. The weather was still overcast, but at Low Point the latitude was taken, being 83° 17′ N.

On May 10th de Long Fiord was passed, from where, assisted by a stiff

wind directly at their backs, they proceeded to Mary Murray Island, which they reached the same day, and where they camped. Here the expedition was detained by snow and storm, until about noon on the 13th the weather improved, and Lockwood and his two companions started towards the east in a wind from the south-west with snow and a temperature of $-11.7°$, all of them suffering greatly from cold and particularly from cold feet. On fair ice they made rapid progress to Cape Hammock where they encountered huge hummocks, and also a lane with open water. It was quite clear when they entered Weyprecht Inlet, the view from which Lockwood describes as "forming a grand panorama, the most remarkable yet observed." After having passed a crack in the ice the party continued. At first the snow was good and hard, but later on it became soft; winds sprang up, with drifting snow, and the sun was rarely to be seen. At noon they reached Lockwood Island, at the northern end of which they camped, the overcast sky preventing the taking of observations throughout the day.

The following morning it was still overcast, and they spent their time in building a cairn with a report, and, finally, in the afternoon they succeeded in determining the latitude, which was 83° 23′ 2″, the highest latitude attained in the northern hemisphere. With great exultation they then unfurled the Stars and Stripes, while Lockwood declared that without the valuable assistance of Brainard throughout the whole of the journey he would never have been able to attain his end. The high mountain behind the cape was ascended in order to see the outermost cape towards the north-east, Cape Kane, and farther east Cape Washington, the fiord between the latter, Hunt Fiord, and the fiord east of Lockwood Island, Conger Inlet, while a small island west of Lockwood Island was named after Brainard. After having completed their observations and raised a cairn with a report the party resolved, on the very same day, to set out on their return journey, as the rations were rapidly giving out.

In the evening of May 16th they broke camp to return, and soon after midnight they passed Mary Murray Island, where a report was deposited in the cairn. A few hours afterwards they camped at Cape Neumeyer, Lockwood's eyes being very bad owing to forced observations in overcast weather. It is mentioned that Weyprecht and De Long Fiords are of "immense extent and have many lateral branches." In the evening they started again, passing Cape Hoffmeyer, where a report was deposited in a cairn, and the capes formerly mentioned were also passed in the course of the day, but the weather being overcast, nothing could be seen.

On the 17th, just after midnight, the party camped at Cape Robeson, after the worst day's travelling which they had experienced since Cape Brevoort. It was impossible to heat the food, and they had to eat it, with lumps of ice, while wind and snow was beating directly against them, and all the time they suffered greatly from pains in the eyes and cold hands.

At 2 a. m. on May 18th they camped in the neighbourhood of Cape Benét, the weather having improved somewhat in the course of the day. The storm, which had been raging for the last twenty-four hours, had made the snow harder and the going better. The three inlets passed seemed to be bays rather than channels. At Cape Benét they saw two ptarmigans, as well as traces of hares and foxes. In the evening they proceeded, all the time with a strong wind against them. The next day, shortly after midnight, they halted off Cape Salor; the weather was now fine and clear, the snow became soft with the heat of the sun, but, nevertheless, the travelling was better than on the journey out, as the surface had become harder on account of the storm. Lockwood mentions that the deep Nordenskiöld Inlet "runs a long distance inwards, as straight as a canal—no land visible at its head." At Cape Frederick circum-meridian observations were taken.

On May 20th, about midnight, Cape Britannia was reached, where the depot was found unmolested and recovered. At 6 a. m. they camped on the ice, and in the afternoon Lockwood went ashore to make collections and found excrements of musk-oxen. In the evening they proceeded, and during the night a fog came on; later the weather became clear without sun, which phenomenon is frequently the precursor of a storm. The snow was good, and the sledge being light, good progress was made. About noon a halt was called, and the sun appeared, giving out much heat. In the evening several cracks in the ice were passed, but they soon froze up. The greater part of the day was spent in camp, partly because all suffered from snow blindness, partly owing to cold and snow. In the morning of the 23rd a camp was pitched off St. George Fiord. The travelling was heavy, the sledge stuck, and only one ration was left. After another halt, extending over twelve hours, they again set out, and shortly after midnight, on May 24th, the coast was reached and followed as far as the tent and cache, which had been left behind. On the following morning an attempt was made at taking a tidal observation, but it failed owing to the strong current.

In the neighbourhood of Frankfield Bay Brainard found Beaumont's cache on a small hill 137 m from the coast. There were no provisions and no cairn, but they found a tent pole, remains of a sledge, cartridges, remains of clothes, etc. In the evening cache No 3 was reached; provisions were taken out, and the party proceeded until midnight, when they camped on the east coast of Hand Bay, Lockwood and Brainard suffering greatly from snow blindness. The weather was warm, and the party cut up the sleeping bags in order to sleep more comfortably.

Stanton Gorge was reached on the 27th, at 2 a. m. and there many traces of foxes were seen. At 3 a. m. cache No 2 was reached from which rations were taken. From Cape Stanton to Black Horn Cliff, which was reached at 4 a. m., progress was made along the snow slopes. Black Horn Cliff was passed along the coast, it being necessary to make constant use of

the axes. Ice conditions had changed completely since the journey out. At midnight camp was made at Drift Point; on the following morning there was a strong westerly wind with snow, and a start was only made shortly before midnight.

After a night's travelling cache No. 1 was reached. Also here conditions were greatly changed while the party had been in the north, and a large piece of hummocky ice had been reduced to half its size. As the party wanted to pass through Cape Valley, progress was made along the coast. After a few hours travelling the cairn at Repulse Harbour was reached, and about midnight camp was pitched in a narrow gorge. All suffered much from snow blindness. There were only two rations left, and the dogs were very hungry.

After some reconnoitring a good road was found, and at 3 a. m. the party started. A wonderful snow cave was passed, being 30 m long and 3 m broad, and high enough to move about upright in. At 5 a. m. the land was passed and Newmann Bay reached through the fourth ravine from Cape Brevoort. The ice in Newmann Bay was very easy to travel on. At 8 a. m. the camp was reached, where the returned sledge party was encountered; they had arrived there on May 5th after having made, in all, six journeys from Cape Bryan. Shortly before midnight on the 29th a start was made, and after three hours' journey the party were off the cape, and the course was shaped across Robeson Channel.

The result of Lockwood's journey was the survey and description of 200 km of unknown coast and valuable information of animal life and ice conditions along this coast.

In the following year Lockwood attempted to penetrate farther east than in 1882. The expedition which, owing to the experience of preceding years, was better equipped for the purpose, started on May 25th and already on April 1st reached Black Horn Cliffs, where they encountered open water along the shore, while Lockwood, from a 390 m high point, saw open water as far as Cape Henry. The temperature fell to —23° C., and the water along the coast froze so that it could be traversed by sledges, and Lockwood resolved to proceed in an easterly direction. Shortly after the expedition had set foot on the coast ice, the great pack ice went into drift in a northern direction, and the expedition narrowly escaped with their lives. Lockwood gave up all thought of further progress and returned without having achieved anything beyond the results of the preceding journey.

In 1883 the Second Dickson Expedition was sent out, consisting of the leader, Professor Nordenskiöld, accompanied by six scientists, including Dr. Nathorst. The object of this expedition was to investigate the ice conditions of the southern part of the east coast of Greenland, to pass along the west coast of Greenland as far as Cape York, all the time carrying on

scientific researches at the various stopping places, and finally to undertake a journey across the inland ice, ascending from Aulatsivik Fiord.

In the "Sophia" the expedition started from Marstrand on May 25th, and on June 12th, after a short stay at Rödefiord and at Reykiavik, it reached the east coast of Greenland in lat. 64° 40′ N., passed south along the ice belt, stopped at Julianehaab and Godhavn and then went south to Aulatsivik Fiord. Here Nordenskiöld, accompanied by Dr. Berlin and Kjellström, ascended the inland ice and succeeded in penetrating 120 km into the interior, attaining a height of 1510 m, but the Lapps belonging to the expedition penetrated 230 km farther and attained a height of 1947 m.

At the same time that Nordenskiöld started on his journey, the "Sophia" commanded by Dr. Nathorst, went north, stopping at Upernivik, Tasiussaq and Ivssugigsoq, a little to the north of Cape York. Then the "Sophia" again went south, stopping at a few places in the Vaigat, Godhavn and Egedesminde, Nordenskiöld in the meantime having arrived at the latter place.

The members of the expedition now once more being united, the "Sophia," on August 19th, called at Ivigtût, on August 23rd at Julianehaab, in the neighbourhood of which archæological investigations were carried on, and on August 26th at Friederichsthal. On August 29th the expedition started for the east coast, where it landed in lat. 65° 30′ N., the first successful attempt of landing south of lat. 70° N., and the "Sophia" anchored in a small bay which was given the name of King Oscar's Harbour. After a few days' stay off the coast, the "Sophia" shaped her course for home, and on September 27th arrived at Gothenburg.

During the whole of the journey hydrographic observations were undertaken whenever circumstances permitted. As to the results of the expedition, special mention may be made of the interesting observations from the journey along the inland ice, the landing on the east coast of Greenland, the valuable collections of palæontological, zoological and ethnographical material, and finally hydrographical investigations (A. E. Nordenskiöld: Den andra Dicksonska Expeditionen till Grönland, 1883, Stockholm, 1885).

In the years 1884, 1886 and 1889 the cruiser "Fylla," which during the summer months was stationed off the coast of Greenland, carried on botanical and zoological investigations in Davis Strait, though only to the extent compatible with her duties. In 1884 the "Fylla" was commanded by Capt. C. Normann, and on board were Professor Eugen Warming, Dr. H. Topsöe and Th. Holm. The botanical and hydrographical results are to be found in Medd. o. G. VII, VIII and XII. In 1886 the ship was commanded by Capt. Bräem, who was joined by Dr. Kolderup-Rosenvinge. The botanical results of the journey are to be found in Medd. o. G. III, the hydrographical ones in Medd. o. G. VIII. In 1889 the "Fylla" was commanded by Capt. C. F. Wandel; the hydrographical results of this journey are contained in Medd. o. G. VII.

In 1888 Nansen made his famous journey across the inland ice of Greenland. With his five companions he left Norway in a sealing steamer, and already on June 5th he reached the ice off the east coast of Greenland in lat. 65° 30′ N. On July 17th, 20 km out, the expedition left the ship in two boats in order to reach the shore, but their progress was checked by the ice, and they were carried by the current towards the south, and only after having been adrift for twelve days and nights did they manage to reach the shore in lat. 61½° N. In the open water the expedition made its way north again as far as lat. 64½° N., where the ascent began on August 16th.

Owing to cold, storms and the lateness of the season, the original plan of reaching Disko Bay had to be abandoned as early as August 27th, and the course was shaped for the settlement Godthaab. After 40 days' travelling the head of Ameralik Fiord was reached, and from there, with great dangers and hardships, the journey was continued towards Godthaab.

As the most important results of the journey must be mentioned the knowledge acquired of the traversed regions, the determination of the profile of the inland ice and the meteorological observations, the lowest temperature registered during the crossing of the inland ice being —45° C. and the greatest height 2719 m. (Paa Ski over Grönland, Christiania, 1890).

In 1895 and 1896 the "Ingolf" Expedition was sent out with the present author, Capt. C. F. Wandel in command and a scientific staff consisting of Prof. H. Jungersen, Dr. H. J. Hansen, H. Knudsen and Wesenberg-Lund. In the course of 1895 investigations were carried out in Davis Strait, in 1896 in Denmark Strait as far as Jan Mayen, with ample results from the point of view of hydrography and zoology (Ingolf-Expeditionen, udgivet af Direktionen for Universitetets zoologiske Musæum).

Among the most interesting figures in connection with the traversing of the inland ice must be mentioned R. E. Peary, engineer of the U. S. Navy. His first attempt was made in 1886, when together with the Dane Majgaard, he started from the west coast in lat. 69½° N. and penetrated as far as 180 km on the inland ice.

In 1891 Peary renewed his attempt, this time accompanied by his wife and five men, including Dr. F. A. Cook and Eivind Astrup. About the end of June he left Upernivik in the "Kite," heading for the northern part of Greenland, and anchored in McCormick Bay, where he went into winter quarters.

In 1892 he investigated Inglefield Gulf, and on April 30th he set out on his journey across the inland ice in a north-easterly direction, accompanied by Cook, Gibson and Astrup, with 20 dogs and 4 sledges. 200 km from the starting point Cook and Gibson were sent back, and Peary continued with Astrup and 2 sledges, until on June 26th they reached the north point of the inland ice, in lat. 82° N. near the north-eastern boundary, where they saw a depression running from the north-west in an easterly direction. A little

later Peary saw an opening in the cliffs, and when after a few days they reached Navy Cliff, they realized that this opening had been the first glimpse of the great East Coast Fiord, which was eventually called Independence Fiord.

The country to the north of this fiord was called Heilprin Land, a more distant tract, Melville Land, and a large glacier in the south, Academy Glacier. Towards the east Peary saw what he erronously supposed to be the sea, and he further declared Greenland to be an island, thinking that he saw Peary Channel debouching into Independence Bay. On July 5th a report of the journey was left in a cairn on Navy Cliff; on August 5th Peary was back at his winter quarters, and during the latter part of that month the expedition left for U. S. A.

In 1893 Peary landed in Bowdoin Bay. His object was to continue his investigations from 1892, and on March 6th he ascended the inland ice with 6 men, 12 sledges and 92 dogs. They travelled for 13 days in a north-easterly direction, when two of the members of the expedition had to be sent home owing to frozen feet, and thus Peary's following was reduced to four. After a fortnight, in the course of which they advanced 204 km, Peary and his four followers turned back, leaving their sledges behind and depositing as much of their dog's food as they possibly could spare; on April 19th they arrived at Bowdoin Bay with only 26 of 92 dogs and all of them utterly exhausted.

In the same year the northern part of Melville Bay was mapped by Astrup. Though the prospects of crossing the inland ice in 1895 were extremely doubtful, and Peary's supplies of provision and fuel were small, he, nevertheless, decided not to return in the autumn, but remained there during the winter 1894—95 with Lee and Henson. On April 1st, 1895, he started with the two men, 6 Eskimos, 60 dogs and 6 sledges. After having covered a distance of 200 km along the inland ice, without being able to find the pemmican left there in the preceding year, he sent back the Eskimos and continued with 42 dogs and 3 sledges, in a temperature varying between —10° and —43° C. The height increased to 2360 m, violent snow storms were raging, and the dogs died. At last Peary continued with 11 exhausted dogs, 1 sledge and Lee, whose feet were frost-bitten, and after desperate efforts the expedition finally reached Independence Bay. In this part of the coast below the glacier they fortunately fell in with a herd of musk-oxen, a much needed addition to their provisions. The relief, however, was only temporary, and they where obliged to return with the utmost speed, having only 9 dogs and provisions for 17 days. In the most pitiable state Peary and his followers reached Bowdoin Bay on June 25th and there they obtained passage, arriving in Newfoundland on September 21st, 1895.

Already the following year, 1896, Peary landed at Cape York, in order to

get men for the shipping of the greatest of the three meteorites which in 1894 he had found on a small island, 56 km east of this cape, the two smaller having already been brought home in 1894. The weight of the greatest of these meteorites was 40 tons.

As to the other arctic journeys which Peary undertook in the course of the following years, only one, his sledge journey in 1900, had Greenland as its destination. He started from Etah in the month of March, and following the north coast of Greenland he reached, on May 13th, its northermost point in lat. 83° 39′ N. After a journey in a northern direction across the sea ice he continued eastwards as far as Cape Clarence Wyckoff from where he started on his homeward journey.

As results of Peary's journeys must be mentioned: an increased knowledge of northern Greenland; furthermore, his establishment of the insularity of Greenland, his ethnological and ethnographical studies of the Cape York Eskimos, his investigations of the glaciers in Inglefield Gulf, and, finally, his demonstration of the richer animal life and vegetation along the north-east coast of Greenland, as compared with more southerly regions (Josephine Peary: My Arctic Journal, London, 1894; R. E. Peary: Northward over the Great Ice, New York, 1898; A. W. Greely: A Handbook of Northern Discoveries, Boston, 1910).

In 1891—92—93 the exploration of the inland ice, planned by the Geographical Society of Berlin, took place under the leadership of Erich von Drygalski, the chief object of these investigations being the motion of the inland ice.

A preliminary expedition was undertaken in 1891 by Drygalski and the meteorologist Baschin. During a six weeks' stay in Greenland they visited Jacobshavn ice current, Ũmánaq Fiord, the glaciers Ujaragtôrssuaq and Kome, Sermilik ice current, Ikerasak, Qarajak ice current, etc., the result of this journey being that the Qarajak nunataq was selected as the basis of the main expedition.

The members of the main expedition of 1892 were, besides Drygalski, Dr. Ernest Vanhöffen, zoologist, and Dr. Hermann Stade, meteorologist. The expedition arrived in Ũmánaq on June 27th, 1892. On August 9th the station was established on Qarajak Nunataq, and the observations began; at the same time shorter trips were undertaken along the coast; soundings and zoological researches were made in Qarajak Fiord, and in the winter four long sledge journeys were made on the inland ice.

The ample results of this expedition, which left Greenland on August 27th, 1883, were published in: Erich von Drygalski, Groenland Expedition der Gesellschaft für Erdkunde zu Berlin. 2 vol. Berlin, 1897.

In 1899 an expedition was undertaken to North-east Greenland, under the leadership of the Swede, Professor Nathorst. The object of this expedition was—if possible—to come to the relief of André, but as the expedition was

to traverse regions which were little or practically not at all explored, he was accompanied by a scientific staff consisting of five members.

The expedition left Stockholm on May 20th, on board the sealing vessel "Antarctic;" on June 12th it arrived in the Drivtömmerbugten on Jan Mayen, which it left after a short stay, entered the pack off the east coast of Greenland, east of Pendulum Island, penetrated through the ice, on June 27th, and on July 2nd reached the solid land floe.

Short stays were made at Pendulum, Sabine and Walrus Islands, and provisions were laid out for Sverdrup. Then the "Antarctic" went south, and after a visit to Hurry Inlet the expedition once more headed north, on August 7th arriving in Franz Joseph Fiord. Here it remained until August 30th, when it left for home.

The results of the expedition were the discovery of King Oscar Fiord, the charting of the latter and all the surrounding minor fiords; geological, zoological and botanical collections, as well as hydrographical and meteorological observations, but as to any traces of André the result was negative. (A. G. Nathorst: Två Somrar i Norra Ishav).

In 1901 a Swedish expedition was sent out to the east coast of Greenland under Gustav Koltkoff, the tasks of this expedition being exclusively zoological. On board the whaling vessel "Fridthjof" the expedition arrived in Mackenzie Bay on July 31st, and made a cruise in a northern direction as far as lat. 74° 52′ N. It reached Franz Joseph Fiord on August 14th and Musko Fiord on August 15th; in the latter place it remained until August 23rd and then finally left the east coast of Greenland on August 25th.

In 1902—04 the Danish Literary Greenland Expedition was undertaken under the leadership of the author L. Mylius-Erichsen, the object of this expedition being to study the Eskimos of Cape York.

Melville Bay was traversed twice, and it was during this stay in Greenland that Mylius-Erichsen planned his later expedition to North-east Greenland. (Mylius-Erichsen & Harald Moltke: Grönland, Köbenhavn, 1906).

In 1905 the Duke of Orleans bought a screw bark, the "Belgica," for a journey in the arctic waters with North Greenland as his final destination. The commander of the vessel was de Gerlache, and the other members of the expedition were: J. Récamier, physician; R. Bergendahl, ship's officer; E. Merité, painter and naturalist; E. Kofoed, biologist; A. Carlsen, engineer, and a crew consisting of thirteen men.

The vessel, which had been equipped for the journey through the ice, left Bergen on May 24th and headed for Spitzbergen, on whose west coast it stayed until July 7th, when the course was shaped in a north-westerly direction, towards the coast of Greenland. After having passed a good deal of loose ice the vessel, on the 9th, in lat. 80° 17′ 5″ N. and long. 5° 40′ E., encountered the solid, impenetrable Greenland ice and followed it in a south-

ern direction with a good many ice obstacles. On the 20th the firm edge of the ice trended west, which direction was followed until, on the 27th, the vessel was off Cape Bismarck, where the Duke to his surprise and, as he says, to his great disappointment, met with a sealer. The course was shaped in a northerly direction along the coast, as the captain of the sealer stated that ice conditions in the north were unusually good. The other locality along the coast where a landing was made, was called "Terre de Francs;" here the French colours were hoisted, and a large bay farther north was named Baie d'Orléans, and its most easterly headland Cape Philippe where, on July 20th, a cairn was raised and a report deposited.

The coast was followed in a northerly direction along the edge of the ice in comparatively open water, a complete determination and description of the coast being given, while the Duke, who was a keen hunter, killed the comparatively many bears appearing on the ice. All the way from Spitzbergen soundings of depths were undertaken several times in the course of the day, as well as dredgings and collection of plancton.

On July 31st in lat. 78° 16′ N. and long. 16° 21′ W. progress in a northerly direction was stopped by impenetrable ice, and the Duke resolved to return, but was persuaded by the captain and Récamier to make a short cruise in an easterly direction, in the course of which, in difficult ice and fogs, depths were found from 200 m decreasing to 60 m at a distance of 50 km from the land-ice. The bank found was called Banc de Belgica.

In fog and ice the vessel reached the firm ice, but it was not until August 2nd that the weather became clear, so that the coast could be determined from Cape Philippe in a northern direction as far as the eye could reach. The course was shaped in clear weather along the land ice, and a successful attempt was made at obtaining a complete map of the traversed coast with its high mountains and the islands situated in front of it; from these observations it appears that Cape Philippe is situated on an island 25 km from the shore.

An attempt at going ashore at Baie d'Orléans failed owing to the broad coast water; a high mountain at the head of the fiord was named Cape Récamier. On October 5th the vessel was off Cape Bismarck, and the expedition succeeded in uniting the survey of the coast undertaken with that of the Germania Expedition in 1870, which had been prevented by the fog. At Cape Bismarck itself the land ice was narrow, and a descent was made by several of the members of the expedition, who found a rich flora and some long deserted Eskimo huts.

On August 6th the voyage was resumed, but for a time solid ice necessitated a northern course, and then the southern Koldewey Island was reached once more; here landing was again attempted and deserted Eskimo huts found, but progress was abruptly interrupted by a walrus hunt.

On August 7th the course was shaped in a northerly direction in order

to avoid the firm ice and in the night between this and the following day, the vessel headed south and got into open water, heading for Reykjavik.

The Belgica Expedition supplied information of a hitherto unknown coast, besides yielding valuable zoological and botanical results.

In 1909 the Duke of Orléans, with the same vessel and the same captain, undertook a cruise in the same waters, the chief object of which was hunting; in any case no report is at hand regarding this trip. A number of soundings taken in the course of the home journey between lat. 77° and 72° N. show that there is a shallow of less than 300 m at a distance of about 280 km from the shore, and a rapid decline to the oceanic depth.

In 1906—08 the "Danmark" Expedition was undertaken under the leadership of Mylius-Erichsen. The expenses were partly defrayed by the Government and the Carlsberg-Fund, partly raised by private subscriptions, and the object of the expedition was to explore the whole of the large coast stretch from Cape Bismarck (lat. 77° 0′ N.) to the extreme point of Peary's journey in 1900, Cape Clarence Wyckoff (lat. 82° 37′ N.). Except that the Duke of Orléans in 1905 had landed on a small island in lat. 77° 30′ this distance was entirely unknown.

The members of the "Danmark" Expedition were Lieutenants of the Royal Navy A. Trolle and H. Bidstrup; Lieutenant (now Colonel) J. P. Kock and Lieutenant Höeg-Hagen; H. Jarner, geologist; Andr. Lundager, botanist; A. L. V. Manniche and Fritz Johansen, zoologists; A. Wegener and Peter Freuchen, meteorologists; J. Lindhard, physiologist; further, the painters Berthelsen and Achton-Friis, the boatswain Thostrup, and the three Greenlanders, Brønlund, Tobias and Hendrik.

In the "Danmark" the expedition left Copenhagen on June 24th 1906, called at the Faroes on July 12th in order to ship coal and Greenland dogs, reached Koldewey Island on August 13th and on August 17th entered its winter harbour, 7 km north-west of Cape Bismarck, where the house and observatories of the expedition were erected on land. Boat journeys to Cape Marie Valdemar, Dove Bay, Cape Bismarck and Koldewey Islands were undertaken at once, and in October began the laying out of provisions in a northern direction, while six research journeys, among which one to Germania Harbour, about 300 km towards the south, were carried out before the end of the year. The remainder of the winter was spent in research work and short sledge journeys. On March 28th the great northward expedition started, consisting of 10 men, 10 sledges and 85 dogs. In about lat. 80° 9′ N. two men and two sledges, and about 80° 44′ again two men and two sledges were sent back, while the remainder continued, very disappointed that the coast was still passing in a north-easterly direction, and not, as had been supposed, trending west, which meant a longer journey and an unforeseen consumption of provisions; finally, in 81° 30′ N. lat. and 18° W. long, the expedition reached the north-eastern headland of the coast, and

after laying down the last depot, it divided on May 1st, one party, consisting of Mylius-Erichsen, Höeg-Hagen and Brønlund, to look for Peary Channel, the other party, Koch, Bertelsen and Tobias, to head for Peary's southernmost point on the east side of Peary Land. On May 12th Koch reached his destination, *viz.* Cape Bridgeman, about 40 miles from Cape Clarence Wyckoff; he was lucky enough to fall in with musk-oxen, a welcome addition to his greatly reduced supplies, and he reached the ship on June 23rd.

On May 27th Koch, then on his return journey, had unexpectedly met Mylius-Erichsen off Cape Rigsdagen. The latter told him that he had followed the coast line, firmly believing that he would thus reach Peary Channel, but after having wandered along the coast for a long time he found himself in a 200 km long fiord, now Danmark Fiord, from which he had wearily worked his way; by this détour a good deal of time had been lost, and as Koch, furthermore, maintained having seen the head of Independ ence Bay with Academy Glacier, it was arranged that Mylius-Erichsen should return with Koch. In the course of the following night Mylius-Erichsen and Höeg-Hagen, however, went into the mountains and received the impression that the remaining part of the coast could be traversed in a few days, and they then made the fatal resolution of continuing in a western direction and devoting a few days to Independence Bay and Peary Channel.

As already mentioned, Koch returned to the ship, but summer went, and winter came without any trace of Mylius-Erichsen and his two companions. On board and round the "Danmark" the work went on as before with sledge journeys and scientific work. Not until September 22nd was the ice sufficiently solid to permit of sending out a relief expedition, which reached the Malemuk Mountain, where further progress was stopped by the open water, and on November 2nd it was back at winter quarters. On March 10th a new expedition started, consisting of Koch and the Greenlander Tobias; on March 19th they reached the depot on Lambert Land, and here they learned the tragic fate of Mylius-Erichsen and his companions. In a small cave they found the dead body of Brønlund, and at his feet there was a box containing a bottle with Höeg-Hagen's map sketches and Brønlund's own diary: in the latter it was stated that Mylius-Erichsen and Höeg-Hagen had died on November 15th and 17th respectively, on their way back across the Seventy-nine Fiord, and Brønlund himself was unable to continue, because of his frost-bitten feet and the darkness. The remainder of the diary was written in Greenlandic, and it appeared from the latter that the melting of the ice had begun on June 14th, after which sledge-driving became so exhausting that the dogs, which for a long time had not been sufficiently fed, were unable to pull and so must be left behind. The return journey, which began at the end of August, was an increasing struggle against hunger, and things had to be left behind in order to facilitate progress; between August 31st and October 19th there were no entries in the diary, the last one being

to the effect that they had ascended the inland ice and that the fifth and last dog was dead. The diaries of Mylius-Erichsen and Höeg-Hagen were not found. The body of Brønlund remained untouched in the cave, which was covered. Mylius-Erichsen had attained his goal, for it appeared from the diary that they had been in Independence Bay in the month of June.

During the following spring and summer journeys and investigations were continued until about July, when the "Danmark" left her winter harbour, got out of the ice on July 21st, and arrived in Copenhagen on August 23rd.

The expedition had accomplished its task, but at the cost of three human lives. An account of this expedition with its ample results is contained in Medd. o. G. XLI—XLVI.

The "Danmark" Expedition was succeeded by the "Alabama" Expedition 1909—12, planned and carried out by Capt. Ejnar Mikkelsen, the object of which was to find the diaries of Mylius-Erichsen and Höeg-Hagen. This expedition was sent out by the same committee which had sent out the former expedition, and expenses were partly provided by the Government and partly raised by private subscriptions. Besides the leader the following six men took part in this expedition: Lieut. Laub, R. N., Lieut. C. Jørgensen; J. Iversen, engineer, the mates H. Olsen and G. Poulsen and C. Unger, carpenter.

On June 20th, 1909, the expedition left Copenhagen on board the yacht "Alabama," called at the Faroes, where it was to receive its dogs; but when the latter arrived some were dead and the remainder so ill that they had to be killed, and the "Alabama" was directed to Angmagssalik, where the necessary dogs were secured. In the meantime another accident had occurred, in that the engineer was taken ill, and an exchange had to be made with an engineer from the man-of-war stationed at Iceland. On August 6th the "Alabama" left Iceland, and after several rough encounters with the ice she anchored, on August 25th, in a small harbour on Shannon Island, and shortly afterwards the expedition went into winter quarters at Cape Souci.

On September 25th Mikkelsen, Jørgensen and Iversen started north, and on October 31st they reached the depot on Lambert Land and the cave with the body of Brønlund; his pockets were searched, but nothing was discovered beyond what had already been found by Koch in 1908, and his body was buried. For three days the neighbourhood was searched in a northern direction, with a view to finding the bodies of Mylius-Erichsen and Högh-Hagen, but without avail, and on December 17th the expedition was back at the ship. After Christmas preparations began for the long sledge journey and the laying out of provisions in a northern direction. On March 3rd Mikkelsen and Iversen started, accompanied by Laub, Olsen and Poulsen. They ascended the inland ice on March 24th; on April 10th the two

parties separated, Mikkelsen and Iversen to go north, while the other party investigated the west side of Queen Louise Land and returned by the same route, along which the ascent on the inland ice had taken place.

On their return, on May 23rd, the three men found the "Alabama" submerged; probably owing to the damage received in the ice she had sprung a leak on March 15th, and everything on board had to be carried ashore with the greatest speed, while a house was built of planks taken from the wrecked ship, of which, finally, only the deck was above water. Reports of what had taken place were deposited on the southern headland of Shannon Island and at Bass Rock, which latter was already found on July 27th by the sealing vessel, the "7de Juni." As Mikkelsen and Iversen had not yet arrived on August 1st, everything was made ready for their return, and the remainder of the expedition left in the "7de Juni."

On May 18th Mikkelsen and Iversen penetrated into the Danmark Fiord, followed its western coast and, on May 22nd, found a cairn with a report written by Mylius-Erichsen and dated September, 1907. Upon the information contained in this report they searched farther and found another cairn with a report, dated August 8th, 1907.

In the latter report it is stated that the Peary Channel does not exist, and that Brønlund Fiord and Hagen Fiord have been investigated; furthermore, that the higher temperature with the resulting melting water on the ice checks all advance and weakens their dogs; that the food problem becomes more pressing and that they resort to the Danmark Fiord in the hope of obtaining more game.

In the former report it is stated that the heavy going still places obstacles in their way, thus making it impossible for them to reach the head of the fiord; that they abandon their original plan and attempt to get out of the fiord and reach the outer coast with provisions for 15 days, hoping to reach the ship in the course of 5—6 weeks by means of bear hunting and the provisions left in those parts.

After many consultations Mikkelsen and Iversen abandoned the idea of penetrating farther into Independence Bay, and on May 28th they started on their return journey, which was attended by all the usual difficulties attaching to sledge travelling in summer, to which must further be added the scarcity of game; at Lambert-Land their last dog died, and constantly struggling against hunger and storms they were forced to leave their tent, sleeping bags and sledge at a place 30 km from Danmark Harbour, which they finally reached on September 18th in a state of utter collapse.

After having spent some time in the house of the "Danmark" Expedition, and having provided themselves with a new outfit they went north in order to find the diaries they had been obliged to leave behind at a skerry, but after a seven days' march the weather forced them to give up the attempt. They resolved to return to the "Alabama" and from there to go north in the

course of the following year. On November 5th they once more left Danmark Harbour to go south, with as much food as they were able to carry, but when their provisions were beginning to give out, they left almost everything behind, and greatly weakened by hunger and cold they reached the winter harbour on November 25th. Here they found the house well provided, and at the same time they learned, to their dismay, that the "Alabama" had sunk.

In the early spring they went north in order to bring back the missing diaries and papers, and having got everything, with the exception of Mikkelsen's diary, which had been destroyed by a bear, they returned to their winter harbour.

One more winter the two men were forced to spend on the east coast, until finally, in July, 1912, a steamer put in at the shore and brought them home.

The results of the expedition were that the knowledge of the marginal zone of the inland ice was increased; that it was proved by the bringing home of the diary of Mylius-Erichsen that Peary Channel did not exist; further, observations were made of the ice along the coast from Danmark Harbour to Shannon Island, as well as meteorological observations (M. o. G. LII.)

In 1912 the first Thule-Expedition was undertaken by the author Knud Rasmussen, accompanied by Peter Freuchen and two Greenlanders. Knud Rasmussen's plan had been to head north from the Thule station, as far as Nordenskiöld Inlet, and from there towards Peary Channel, but when in 1911 the report was received of the anxiety felt for Ejnar Mikkelsen, he resolved to come to his relief. This necessitated a journey to Upernivik for additional provisions and travelling outfit in view of the new object of the journey, and on April 14th the expedition ascended the inland ice, above Clemens Markhams Glacier, sent 9 sledges from Humboldt Glacier to Peabody Bay, on the chance of meeting with Mikkelsen, and then continued towards the western extremity of Danmark Fiord. Rasmussen entered the fiord on May 31st, and, continuing along the ice out of the fiord, he found, on June 4th, the cairn erected by Mylius-Erichsen in his summer camp of 1907, but as it was empty, he concluded that Mikkelsen had not been there. Then he passed Hagen Fiord and went across to Peary Land, where the expedition met with abundant game and recovered its strength; and here interesting remains of Eskimo habitions were found. On June 17th the expedition reached the head of Independence Bay and once more confirmed the fact that Peary Channel did not go through. After having ascended the inland ice the expedition headed for Navy Cliff, across Nyeboe's Glacier; it reached Navy Cliff on July 15th, and there succeeded in finding Peary's cairn with his report of July 5th, 1892. Not until August 8th did the weather permit their going home, but on the return journey Rasmussen and Freuchen

were so exhausted that it was at times necessary to drive them on a sledge. On September 15th the expedition was back at Thule.

Besides what has been mentioned above, the expedition obtained valuable results from the point of view of zoology, botany and meteorology, and a further point of interest was its travelling technique, which in several respects was a novel one adopted from Eskimo methods, such as the building of snow huts, the handling of sledges, the supply of provisions, etc. (Medd. o. G. LI.)

In 1912—13 the Second Swiss-Greenland expedition was carried out under A. d. Quervain; as early as in 1909 Quervain, accompanied by Swiss naturalists, had visited Greenland, having, *inter alia*, ascended the inland ice at Qarajak-Fiord and penetrated 125 km inland.

The other members of this expedition, the chief object of which was to cross the inland ice from west to east, were Dr. Høszli, the architect Fick, the engineer Gaule, Professor Mercanton, Dr. Stolberg and Dr. Jost, the three latter forming the so-called wintering party, who were to accompany the others part of the way across the inland ice.

On April 2nd, 1912, the expedition left Copenhagen, after having arranged for provisions to be deposited near Angmagssalik, and after longer stays at Holsteinsborg and Godhavn, it ascended the inland ice, on June 10th, well provided with dogs and sledges; on June 13th the wintering party returned, and after 41 days' travelling, with 29 camping places, the expedition reached the east coast, where it found the provisions which had been laid down in the Sermilik Fiord; then it made its way to Angmagssalik from where it returned.

The result was a 700 km long profile of Greenland and observations of the physics and meteorology of the inland ice.

The wintering party spent six weeks on a nunataq, 800 m from the margin of the inland ice, and at a height of 535 m from where it carried on glaciological investigations and made various sledge trips. On September 6th Dr. Mercanton left for home, while Dr. Stolberg and Dr. Jost went to stay at the Biological Station on Disko Island, with the object of carrying on meteorological observations and studying the ice. The complete scientific results of the expedition are published in "Denkschriften der Schweizerischen Naturforschenden Gesellschaft" and Medd. o. G. LIX.

In 1912—13 the so-called Danish Voyage of Investigation was undertaken right across North Greenland, from Dronning Louise Land. This expedition was planned and carried out by Capt. J. P. Koch, accompanied by Dr. Alfred Wegener from Berlin. The expenses were partly supplied by the Government and the Carlsberg-Fund, and partly raised by private subscriptions. The object of the expedition was to spend the winter in Dronning Louise Land, with a view to investigating natural, and more especially atmospheric and glaciological conditions in the marginal zone of the inland ice, and finally,

in the spring, to undertake a journey across the inland ice to the settlement Prøven. Profiting by the experiences made on the "Danmark" Expedition Koch determined to employ horses for the transport of the very considerable amount of luggage across the broad open coast land, and for this purpose 16 horses were brought. A depot had been laid down on the west coast at Pingut (lat. 72° 37′ N.) on the margin of the inland ice.

After having crossed Iceland with the 14 horses the expedition, on July 7th, reached Øfiord, went on board the screw steamer "Godthaab" and left on the same day. The "Godthaab" passed to the east of Jan Mayen as far as lat. 76° N., then headed west and after a 9 days' rough passage in the pack-ice of East Greenland she anchored, on July 21st, in Danmark Harbour; the following day she passed on to Stormkap, where horses and supplies were unloaded, and on July 24th she left for home.

Partly in a barge which had been brought for the purpose and was towed by a motor boat, partly over land by means of the horses, the expedition managed to get everything transported to Cape Stop, but owing to the state of the ice, the transport by sea was attended with the greatest difficulties, and not until September 12th was everything ready.

After a dangerous trip across the ice of Borg Fiord, Koch and Wegener sought and found a favourable place for ascending the inland ice; on this trip Wegener fell and broke a rib, so that he was disabled for some time. On September 19th the transport across Borg Fiord commenced, and on the 28th everything was brought together in the ice valley, through which the ascension was to take place.

When on October 5th everything had been transported on to the inland ice, it was utterly impossible to reach Dronning Louise Land, and so it was resolved to establish a station 3 km within the margin of the ice. On October 9th the house was built and a stable arranged for the six horses, their number having been reduced after the transport was finished. During a short trip Koch himself had met with an accident; he fell into a fissure in the ice and broke his leg, which made him unable to move for a period of seven weeks.

The winter was passed in meteorological and glaciological investigations, observations of auroræ, etc., the lowest temperature registered being —50° C.

On April 19th, 1913, the expedition started on its journey across the ice, in a western direction, and on July 6th the depot at Pingut was reached, the temperature in the meantime having risen to + 2° 8 C. at noon. During the crossing of the inland ice, where a height of 3000 m was reached, the expedition must fight against contrary winds, gales and thick weather with snow, which necessitated frequent halts, with the resulting exhaustion and unforeseen consumption of provisions, and the remaining horses were killed, because they were too exhausted to go on. On July 9th the expedition started from the depot, and the descent began; on July 9th there were only provisions for five days, and everything that it was possible to dispense with

was left in a depot, so as to reduce the total weight of the remaining luggage to 140 kg. On July 11th the expedition reached Laxefiord, which was crossed by means of an improvised ferry. On July 13th the expedition arrived in the plateau of the outer part of the Kangeq Peninsula, where the last pemmican was eaten. On July 15th they reached the sound between the Kangeq Peninsula and Qeqertarssuaq, and here, in order to sustain life, they were obliged to kill their faithful travelling companion, the dog Cloë; but at the very moment that they were going to partake of this sad meal, they caught sight of a boat which they signalled and which took them to Pröven, from where they left for home on August 6th.

In 1916 the Second Thule Expedition was undertaken with Knud Rasmussen as leader, Lauge Koch, geologist and photographer, and the Swedish geologist, Dr. Wulff. The object of this expedition was to survey the remaining unexplored part of the northern coast of Greenland, from St. George Fiord to de Long Fiord; further, to investigate the connecting country between Nordenskiöld Fiord and Independence Fiord, especially with a view to the theory of the migrations of the Eskimos; to carry on investigations as to the existence or non-existence of Eskimo winter houses north of Humboldt Glacier, as well as geological researches from Sherard Osborn Fiord to Peary Land and of the fiords in northernmost Greenland; and, finally, to make a map of Melville Bay with ethnographical investigations of the latter.

On April 18th the expedition arrived in Godhavn, made its way to Melville Bay, attended by great dangers and hardships; traversed the bay under favourable conditions and successfully carried out the tasks appointed in those parts. On June 17th it arrived in Thule, where it met the Croker Expedition and worked together with the members of the latter during the following summer, while the winter was spent in preparations for the journey in 1917. As to the equipment of the expedition light sledges were used, like the ones adopted by the First Thule Expedition,and as to provisions, hunting was relied on.

On April 6th, 1917, the expedition started north. It consisted of the three above-mentioned explorers and four Eskimos, accompanied by an auxiliary expedition with provisions for the early part of the journey. Via Etah it reached, on April 24th, Cape Constitution on Washington Land, having all along the route found numerous Eskimo ruins and made interesting collections of fossils; on April 25th the last letters home were written and sent back with the returning auxiliary expedition. The journey was continued and after having made a distance of 1000 km under great hardships and with very little hunting, the expedition, on May 7th, reached St. George Fiord, where its actual task commenced.

The expedition had started with provisions for two months; half of these were deposited at Dragoon Point at the cairn of Beaumont, while the other

half were consumed on the journey. Knud Rasmussen, however, dared not stay here and commence work, before the means of existence had been made fairly secure by means of game, and they started with 70 rather exhausted dogs, leaving behind 2 sledges and everything which could be dispensed with. Not until they arrived at Victoria did they find game and shot 16 musk-oxen, but in the meantime they had to kill a number of their dogs, partly for food and partly to reduce the number of mouths to be fed. In Victoria Fiord they stayed for a week, in order that the dogs might recover their strength, and the fiord was surveyed. This being accomplished they returned to Dragoon Point. The going was bad, snow storms raged, and the dogs quickly lost strength. Under great difficulties the Gerard Osborne Fiord was mapped and the depot at Dragoon Point recovered; on May 24th they started for Cape May, which was reached on the 25th; then, without obtaining any game, they went on to Cape Wohlgemuth, which was reached on the 29th, and on the following day they met with Wulff who had gone on ahead and shot 6 musk-oxen. The expedition then divided into two parties, one under Wulff which was to go north to de Long Fiord to hunt musk-oxen in the northern region as far as Cape Morris Jessup, while the other party, consisting of Knud Rasmussen, Koch and one Eskimo, were to penetrate to the head of Nordenskiöld Fiord, with the object of mapping the latter, and then across the inland ice to seek the hunting regions at Valmuedalen and to go to the north of Peary Land through Independence Fiord; also Nordenskiöld Inlet was to be mapped and a large fiord, which was later called by the name of I. P. Koch Fiord. The work was carried on under the greatest hardships, with tired dogs and no hunting, and the expedition was detained by snow and storms, suffering greatly from hunger and cold, until June 9th when the Eskimos shot two seals. With renewed strength they once more started east, and at Cape Neumeyer, on June 16th, they met Wulff, who owing to the failure of game had made vain attempts to reach de Long Fiord. Of the 27 dogs with which Wulff had started only 14 were left. Knud Rasmussen was reluctant to turn back so close to his goal, but as shown by the experience of Wulff there was very little to hope for in the way of game, and he only wanted to continue in case his comrades on their own accord offered to assist him in the attempt. Koch and the Eskimo volunteered at once, and when Knud Rasmussen said that two men were required for each sledge, one of Wulff's Eskimos also offered to go. Then it was resolved that in order to save his dogs Wulff and his two Eskimos were to go to Cape Salor, where there was now a chance of getting seal.

On June 16th Knud Rasmussen started, and in the evening he camped a short distance north of Cape Neumeyer. The following day the two Eskimos, who had gone out hunting, returned with a large seal, 3 hares and 3 ptarmigans. All anxiety was at an end, as they were now able to set out for their destination without any fear of scarcity of provisions, and they might even leave 2—3 feedings per team.

On the same evening they started; the going was bad, and they met with contrary winds and snow storms. At Mascart Inlet a sledge was passed, which had been left by Wulff. A seal was sighted, but it was very shy, and they were unable to approach within shooting range, but 3 brand geese were shot. At Low Point they rested for a day; then Jewell Point and Cape Weywood were passed; here they killed 8 hares and 6 ptarmigans and shortly afterwards a seal, so that they had sufficient provisions for the stay in de Long Fiord.

The latter was reached and surveyed, which survey yielded interesting results; a cairn was built, and on June 22nd they started on their return journey. For a while Knud Rasmussen deliberated the possibility of continuing as far as Cape Bridgeman, but he had reached his goal, and, besides, he had arrived at the result that the immigration of the Eskimos into Greenland could not have taken place along the north coast of the latter country, partly because of the apparent state of the soil to the east of de Long Fiord, and partly on account of the absence of Eskimo ruins in the latter part of the distance covered.

As mentioned above, they started on their return journey with 3 sledges, and on the same day (June 22nd), they reached Cape Lockwood. Owing to the rise of temperature and the consequent melting of the snow the going was bad, and there was water under the snow, which made sledging more difficult. On June 27th they passed Cape Neumeyer, where 3 seals were shot, and shortly after having passed Cape Salor they met with Wulff and his two men, who had 9 dogs left and were well provided with seal meat. After a day's rest the journey was continued; the going was still bad, and the temperature —3° 6′ was wearying; on the morning of July 1st they had only made a distance of 10 km, and the dogs were tired, so that they were obliged to halt off Nordenskiöld Fiord. The outlines of the head of this fiord explain, according to Knud Rasmussen, the fact of Peary's taking it for an entrance to a channel across to Independence Fiord.

On July 3rd the journey was continued; owing to the higher temperature the rough Polar ice was transformed into channels and lakes; all day long they had to walk in ice-water; the dogs were greatly weakened; one dog went down and refused to rise, and tents were pitched on ice-islands. The meat was giving out, but after they had passed MacMillan Valley, they were fortunate enough to get 13 musk-oxen.

With renewed strength and meat for a week for the men and the remaining 18 dogs the journey was resumed, on July 15th, under the same hardships as before, while the ice-water made it difficult for them to keep the damp from photos and diaries. At Cape May conditions improved, and across Sherard Osborne Fiord, from where the ascent to the inland ice was to take place, the ice was free of water, and the sledging fairly easy, one man on each well-loaded sledge. They pitched their tents in the middle of the

fiord, and on the following day they continued in the direction of Dragoon Point, where the supplies which had been left behind were to be fetched. The going became worse, but, nevertheless, they reached Dragoon Point on the following day. The supplies were recovered, but they obtained no seals, as those which they shot were so lean that they sank at once. After having taken stock of the remaining provisions they realized that, with small rations and by killing some of their dogs, they would be able to reach south of Humboldt Glacier; once there, they were again within the hunting district of the Etah Eskimos. On July 21st they started towards the interior, but the going was very tiring and the weather rough. When the first halt was called, one of the Eskimos went out hunting; he did not return, and for three days they looked for him far and wide, but in vain. At last they had to give him up as lost, and, depressed and saddened, they continued on their way.

It was a matter of life or death for them now, and they had to go on over rotten ice, which they would not otherwise have thought of trusting; and all the time three men must walk in front of the dogs in order to drive them forward, On July 26th they succeeded in getting one seal and recovered a little, but otherwise they were in a piteous state, and their footgear and clothes were soaked by ice-water and rain.

Progress was slow; one necessary article after another had to be left behind in order to lighten the sledges; 4 dogs were killed for food, when finally, on August 1st, a seal was obtained. On August 4th they ascended Daniel Bruun Glacier; with half rations they had now sufficient provisions for 20 days and a little seal meat for the dogs. They proceeded slowly across the inland ice, in deep snow, with adverse gales and a temperature of –4° C.; a long detour had to be made in order to pass a deep crevice, which was given the name of the Devil's Crevice, and not until August 10th was the inland ice proper reached. Snow storms and fogs necessitated long halts with intervening short marches; Wulff and Koch suffered from boils, which made progress hard and painful, and on August 17th only 9 dogs were left. Once more the sledges had to be lightened, and everything that could be dispensed with was left behind; on August 21st they drank their last cup of coffee, and only 5 dogs were left, when to their great joy they saw land ahead. But the difficulties still to be surmounted were great; the increasing temperature formed fast-flowing rivers on the ice, which it was hard to pass; and with their diminishing strength a new fear presented itself, the fear of losing the collections, the results of their united efforts. On August 24th, after the last dog had been killed, the expedition reached the coast land. In so far they were saved, but all they had left by way of eatables were a few skin straps, a tube of glycerine and a cupful of tea. Wulff and Koch declared themselves too exhausted to continue until they had had a rest, but the munition supply was too small for a longer stay, and the all

important thing was speedy relief. Consequently, Knud Rasmussen resolved, together with one of the Eskimos, to try to reach Etah, a distance of 270 km, in order to call assistance; the two remaining Eskimos were left behind to assist the exhausted party, and the four of them were to make slow marches in a southerly direction. On August 25th they succeeded in getting 5 hares, and a little strengtherned by these Knud Rasmussen started together with the Eskimo.

It was a very hard journey over rough ground, in ice and snow, but on the fourth day they met an Eskimo from Inglefield Gulf, who with several other hunters had strayed from a camp somewhat farther out. However, the Eskimo encountered had not sufficient provisions for a return to those left behind, and in spite of all efforts it proved impossible to call the other hunters together, so with the dogs of the Eskimo Knud Rasmussen continued the journey at a brisk pace, and on August 30th at 9 p. m. he reached Etah from where on the following day the relief expedition was sent out with provisions, Knud Rasmussen and his Eskimo companion being too exhausted to take part in it.

On September 10th the relief expedition returned with the party which had been left behind, but Wulff was missing. On the day following upon the departure of Knud Rasmussen the four men had resolved to go on, while they had still sufficient strength to do so. Each of them only took a pair of kamiks and a blanket; Wulff, who was even then utterly exhausted, took his reindeer coat, the Eskimos a rifle and a double-barrelled gun with a small supply of munitions, but otherwise everything was left behind with the collections and diaries of Wulff. A hare was shot and eaten raw, but Wulff was too weak to take his ration. On August 27th they continued, but Wulff was only able to make 4 km in three hours. In spite of his enervated state Wulff, however, still made botanical observations, but on the third day he declared that he was unable to go on and preferred to lie down to rest. Still, he wanted the others to go on, and the situation was so desperate that they would have to continue or perish. They had no sledge to place Wulff on, and as they were too tired to carry him, the sad decision was taken of leaving him. Wulff dictated a summary of the vegetation on Inglefield Land, wrote a letter to his parents and his daughter and took leave of his comrades, expressing the solemn hope that they might reach back, and the results of their efforts thus be saved.

They proceeded slowly, Koch being extremely weak, and though they succeeded in getting a little game, it was not sufficient to enable them to return to Wulff; finally, on September 2nd they managed to shoot two reindeer, but then return was out of the question, ten days having elapsed since Wulff's last meal. However, they stayed there for two days, and, as mentioned above, they reached Etah on September 10th.

After having secured the necessary assistance and equipment from the

Inglefield dwelling places, Koch started back, with the twofold object of burying Wulff and of fetching his diaries and notes which had been left behind. Owing to snow and darkness Koch failed to find Wulff, but he secured the collections at Cape Agazis, and with these he returned about the middle of November.

To get a passage home was out of the question, so it was necessary to spend the winter in Greenland. It was, however, impossible to stay at Etah, where the necessary provisions could not be secured, so as soon as Knud Rasmussen had recovered his strength, he left for Thule, on October 1st, in order to make preparations for the wintering of the expedition, and after a very fatiguing journey he arrived in Thule on October 22nd.

The result of the expedition was a copious geographical, geological and botanical material, the preparation of which has been commenced, although it will take several years before the results can be published.

The Third Thule Expedition was sent out with the object of laying out provisions for Roald Ammundsen at Cape Columbia.

The leader of the expedition was Capt. Godfred Hansen, R.N., assisted by the Rev. Gustav Olsen and Polar Eskimos, and it left for Greenland in July, 1919.

The expedition started from Thule on March 8th, arrived at Etah on March 19th, at Fort Conger on April 6th, and at Cape Columbia on April 20th; it started on its return journey on April 27th, was back at Thule on May 25th and left for home on September 19th.

The object of the Fourth Thule Expedition was the collection of popular legends and tales from the east coast. This expedition, which consisted of Knud Rasmussen, accompanied by an Eskimo, started for Angmagssalik on August 25th, and, having finished his work, Knud Rasmussen left for the west coast from where he returned.

The results are made known in "Myter og Sagn fra Grønland" vol. I. 1921.

In 1919 a plan was broached of commemorating the bicentenary of Hans Egedes' landing in Greenland by undertaking an expedition with the object of revising the existing map of the whole of northern Greenland, from the Danish Colonies as far as Danmark Fiord, with a geological map of the north coast and particularly an investigation of the fossiliferous formations, discovered by Lauge Koch in 1917. A committee was formed and the necessary funds raised, partly by a Government grant and partly by private subscription, and Lauge Koch was appointed leader of the so-called "Bicentenary Expedition round the north of Greenland," which was chiefly carried out with Eskimo assistance.

The expedition left Copenhagen on July 15th, 1920, and two months later it reached Cape Robertson, where its supplies were landed, and a house built. From October 5th to November 15th a reconnoitring trip was made with the assistance of Eskimos, extending as far as Kane Basin and right

across the latter to lat. 80° N.; after his return Koch left for Upernivik, partly in order to carry on researches, partly in order to save his small supply of coal.

Koch left Upernivik about the end of January 1921, and in the latter part of February he was back at Cape Robertson. After having laid down a depot at Cape Alexander Koch, himself the only European, started north on March 15th with 19 sledges and arrived at Fort Conger on Grant Land on April 5th, having sent back 9 sledges in the course of the journey; here he remained until April 17th in order to rest his teams and to shoot musk-oxen for dog's food, and then began the journey north of Greenland. From Hand Bay he continued with 3 Eskimos and 32 dogs, the remainder being sent back. Without any difficulties Koch reached de Long Fiord, recommenced the survey of the country, which had been interrupted in 1917, and on May 13th the Danish flag was hoisted on the northern extremity of Greenland; on May 21st he reached Cape Bridgemann, the northernmost point of the "Danmark" Expedition, the whole coast of Greenland thus having been traversed by Danish explorers. The journey along the east coast of Greenland was begun with only 5 boxes of pemmican and a small supply of ground oats, so game was an absolute necessity, but rough weather prevented hunting; half of the dogs had to be killed, and not until May 26th did Koch and his companions manage to shoot 9 musk-oxen.

During the first days of June the journey was continued into Independence Fiord, then into Brønlund Fiord, where Koch succeeded in demonstrating that the famous Peary Channel was a great depression with a lake in the centre. On June 26th the expedition ascended the inland ice, and the following three weeks were spent in mapping the regions round Vildtland and Adam Bjerring Land, as well as in securing provisions for the 700 km long return journey. However, only 2 musk-oxen were obtained, and the provisions which the expedition expected to find on Warming Land had not been laid down owing to illness among the Eskimos, so that Koch and his followers had to kill their dogs in order to sustain life during the last stage of the journey. Favoured by fine weather and a storm which made it possible for them to cover the last 50 km by means of sails, the expedition arrived at the coast with only one dog left, on August 12th. A week later a depot was reached in lat. 80° N., and cartographic and geological investigations were undertaken in the southern part of Washington Land. On October 2nd the expedition reached its house, after a journey extending over 200 days.

While Koch was away, an epidemic had carried away many of the natives, and still more were very weak. Mr. Nygaard, at one time manager of the trading post at Cape York, had been left in charge of the house, and in Koch's absence he had made large botanical collections, in particular from Inglefield Land.

In the middle of November Koch again left for Upernivik in order to replace the dogs he had lost. The passage across Melville Bay was very difficult, as the three Eskimos accompanying him fell ill with influenza, having caught it at Thule, to which the epidemic had been brought by a ship. At Thule Koch met the mechanic Nielsen, who had been sent up there to assist him, and the latter went with him to Upernivik, but on this journey his feet became frost-bitten, and only Koch and one Eskimo were in good health when they arrived at their destination on New Year's Eve.

Not until the month of March was Koch able to start north; in passing various dwelling places he learned of the ravages of the influenza, which had carried away many of the best people, and when he arrived at his house, he had lost several of his dogs owing to lack of food.

It was with a good deal of misgiving that Koch thought of a new journey; a great quantity of snow had fallen, the temperature remained low, the population was weakened by illness, and, finally, he had been informed that the Government of Canada had forbidden the shooting of musk-oxen in Ellesmere Land, a serious drawback in view of the great transport of fossils and the number of dogs required for this purpose.

In April a depot was laid down in lat. 79° N., and on April 22nd Koch started north. He reached Cape Brevoort on the following day, and with the 3 boxes of pemmican left at that place he hoped to be able to remain there and to undertake an investigation of Nyeboes Land. But all work was prevented by rough weather, and on May 30th he had to go south, as the depot was emptied, and the dogs were only saved because he was lucky enough to secure some bears.

On June 13th, in 80° N. lat., Koch met the mechanic Nielsen, who had transported 8 sledges to this place, 6 of which had already been sent home with fossils, while two were being dispatched for the same purpose. After having investigated the coast at Kane Basin Koch reached his house on July 25th. The result of the journey was the mapping of the coast from lat. 78 to 80° N. and the successful transport of the greater part of the fossils.

On September 6th an attempt was made to transport one of the two tractors of the expedition on to the inland ice, but this attempt had to be abandoned owing to the break-down of the engine, and the equipment at hand was utilized for a journey inland, in the course of which the southern part of Inglefield Land was surveyed, while in 79° N. lat. a large collection of cambrian fossils was made. On October 1st Koch was back at his house, and after everything belonging to the expedition had been sent over the inland ice to Thule, Koch left for Upernivik, where he arrived at the end of January, 1923.

In the spring Koch mapped the distance from Cape York to his house, and on May 22nd he went south to Godhavn. His collections, etc. were

brought there by a ship from Thule, and with these he left Greenland and arrived in Copenhagen on October 15th.

The remaining part of the coast of Greenland had been mapped, and, further, the expedition had obtained great results from a point of view of geology and botany.

Of other scientific researches in Greenland, carried out independently of the work of the commission, mention is still to be made of the following:

Since the establisment of the Meteorological Institute in 1872 the latter has set up various meteorological stations in Greenland. Meteorological main stations were established in 1873 at Upernivik, Jacobshavn and Godthaab—the latter with a smaller branch station at Qôrnoq—furthermore, in 1875 at Ivigtût, in 1883 at Nanortalik, in 1894 at Angmagssalik and in 1910 at North Star Bay.

Three times a day—at 8 a. m. at 2 p. m. and at 9 p. m.—these stations, ever since their establishment, have carried on observations of the atmospheric pressure, the temperature and the degree of humidity of the atmosphere, the direction and force of the wind, cloudiness and weather; also, at 2 a. m. observations have been undertaken of the minimum temperature, the maximum temperature and the precipitation within the preceding twenty-four hours. Furthermore, a barograph and a thermograph have been set up at Angmagssalik and North Star Bay, while a barograph was established at Upernivik in 1905 and at Godthaab in 1911.

Besides the above-mentioned meteorological main stations, which are still working, the Institute at present has smaller stations at Julianehaab, Holsteinsborg and Sagdlît, established in the years 1880, 1889 and 1906, respectively. Furthermore, in the course of time 12 smaller stations have been set up along the west coast of Greenland, which stations had to be given up about three to ten years after their establishment, principally because the observer had been transferred, and it had proved impossible to find a local substitute possessed of the necessary qualifications. Of these stations six were situated between lat. 70° and 72° N.

At the smaller stations observations have as a rule only been undertaken of the temperature of the air, wind, cloudiness and weather, and these observations have taken place at 8 a. m., 2 p. m. and 9 p. m.

Since 1874 the meteorological observations from Greenland have been published yearly in "Meteorologisk Aarbog," Part II, being sent out by the Meteorological Institute. As far as the main stations—only excepting Nanortalik—are concerned, these reports include the tridiurnal observations as well as the yearly summary of the latter, whereas in the case of Nanortalik and the smaller stations the records only contain a monthly and a yearly summary of the observations.

Furthermore, the Institute in 1899 published meteorological means and

extremes from the Faroes, Iceland and Greenland (Appendix to the Yearbook of the Danish Meteorological Institute 1898, II Part.)

In 1903—05 the merchant Bernburg sent out two expeditions to the west coast with the object of investigating mining conditions. In 1905 the rational working of Josva's Copper Mine in the Julianehaab District was begun; this, however, was subsequently given up, whereas the working of the graphite mines is being continued with varying profit.

In 1908—09, at the initiative of the Royal Greenland Trading Company, investigations of fishing conditions were carried out along the west coast of Greenland by the zoologist Ad. Jensen (afterwards Professor of Zoology at the University of Copenhagen) on board the "Tjalfe," the object being to obtain information for the benefit of practical fishing.

Already during his first winter (1903—04) in the Cape York District Knud Rasmussen realized the importance of the establishment of a station at Thule or elsewhere in the district, seeing that such a station would lend itself admirably to the task he had set himself, *viz.* to investigate the life and wanderings of the Eskimos. The immediate occasion of the establishment of this station was the fact that Peary, after he had reached the North Pole, was no longer interested in maintaining the intercourse with the Eskimos of the district, and Knud Rasmussen feared that the tribe would be open to other influences from without, plans being entertained, in America as well as in Norway and Germany, of securing a permanent foothold in the district.

Knud Rasmussen first sought the assistance of the Ministery of the Interior, but as he did not succeed in getting the support of the Government, the station was established for private account and always followed the rule that the Eskimos were only supplied with such European merchandise, which was really useful and beneficial to them, and that the station should try and render assistance whenever necessary and justifiable. The trading station is in close touch with the mission station, but works quite independently of the latter. The profit made on the merchandise purchased has hitherto exclusively been used for scientific expeditions.

In 1906 Morten Petersen Porsild, B.Sc., established the Danish Arctic Station on Disko Island. The object of this station was to form the basis of such scientific researches as could only be carried out during longer stays at a place where a laboratory, library and other facilities were at the disposal of the investigators. Since its establishment, Porsild has chiefly been engaged in biological and ethnographical work, and the two working bases attached to it for the use of Danish and foreign investigators have been visited by a number of Danish, Swedish, German, Swiss and American scientists, who have carried on botanical, geological, geophysical and physiological researches, the results of the work of the station being published

in "Meddelelser om Grønland." The station was established by private donation (the gift of Mr. A. Holck) and is being carried on by Government grants.

THE COMMISSION FOR THE DIRECTION OF GEOLOGICAL AND GEOGRAPHICAL INVESTIGATIONS IN GREENLAND

When until the middle of the seventies of the 19th century Denmark had not commenced the sending out of expeditions for the thorough scientific investigation of Greenland, this was not because we did not realize the importance of the matter or our obligations in that direction, but it was simply owing to the difficulty of providing the necessary funds, after the disastrous issue of the war of 1864.

Long before the actual carrying into effect F. Johnstrup, Professor of Mineralogy, had had his plan ready for a systematic investigation of Greenland, but he did not put it forward until there was a prospect of executing it. On August 25th he submitted a proposal to the Ministry of the Interior, to the effect that geological investigations should be undertaken under Danish auspices, as had already been done in practically all other European countries, and at the same time it was pointed out that it would be desirable, with the greatest expediency possible, to start such investigations in Greenland.

In the above-mentioned proposal the following passage occurred: "As regards the dependencies, Greenland in particular should be subjected to a thorough investigation from the point of view of mineralogy and geology, being likewise the one of our dependencies which in recent years has been made the scene of the greatest number of scientific expeditions. The great knowledge of the geognostic conditions of this country is chiefly due to the scientific voyages undertaken by the Danish naturalists and in particular those of Dr. Rink in the years 1848—51; among these voyages must also be included that of the German scientist Giesecke in 1806—13, in so far as he probably undertook it with the support of the Danish Government.

"This widely extended and sparsely populated dependency, however, still offers many points of investigation, and Denmark has a certain obligation not to hold back from further research work which may serve to elucidate some of the most important features of the physics and geology of a country from which the Treasury draws a not inconsiderable revenue. Especially I would point out that for a number of years the working of the cryolite mines alone has yielded an annual income of, as far as I know, a hundred thousand kroner. The extensive use of this mineral for technical purposes, and the accruing considerable annual income is entirely due to the chemical researches of a Danish scientist, Professor Thomsen.

"The part of Greenland which up to the present is least explored, and

where consequently investigations should by preference be inaugurated, is the southern part of the country, in particular the Julianehaab and Frederikshaab Districts, where there are several crystalline rocks, which in themselves are of great importance from a point of view of geology, and which bear a striking resemblance to those occurring in the Scandinavian Peninsula, though at present very little is known of their distribution and formation in southern Greenland.

"Instead of entering into the appertaining details of geology, I prefer to glance at another, physically and geognostically important problem, *viz.* that of the extension and conditions of the inland ice. As to this problem several naturalists still entertain very hazy ideas, and the most fantastic theories are frequently advanced, solely on account of the deficient results obtained from the few and very limited attempts which have hitherto been made towards acquiring knowledge of the inland ice. Statements to the effect that a country free of ice and possibly even inhabited by human beings should be found in the interior of Greenland and other similar assertions, can never be thoroughly disproved until in one or more places the ice is crossed from the western to the eastern coast. By such crossings it would, further, be elucidated whether the inland ice forms a continuous covering of the whole of the interior, or whether it is broken by larger mountainous tracts or only sporadically pierced by solitary peaks. That the latter is the case in several places is known with certainty, but no knowledge exists as to the composition of these mountains. An enterprise like the one here mentioned might, most appropriately, be combined with a geognostic investigation, extending over several years, of the southern country, the part which naturally suggests itself for a crossing from the west to the east coast; there would be ample opportunity to undertake the necessary reconnoitring trips from various points and then to choose place and time, according as it proved most favourable for carrying out the project."

The plan was favourably received by Parliament, and a yearly grant of 10,000 kroner was voted. After expeditions had been sent out to Greenland in 1876 and 1877, with good results, and the importance and many-sidedness of the task had been realized, the Ministry of the Interior on January 11th, 1878, appointed the "Commission for the Direction of Geological and Geographical Investigations in Greenland."

The president of the commission was Professor Johnstrup, and among the members were the director of the Royal Greenland Trading Company H. I. Rink, as well as the Minister of Marine, N. F. Ravn. The first step undertaken by the commission, after elaborating the plan of its future work, was the resolution of starting the publication of "Meddelelser om Grønland," which was to include the results of past and future expeditions, as well as other matters of scientific import in connection with Greenland. Johnstrup undertook the editorship, and upon the whole he was the soul of the

commission until his death in 1894. In 1890 Ravn resigned and was replaced by C. F. Wandel. In 1893 Rink died, and Wandel directed the work of the commission until 1896, when commander (now Captain) G. Holm and the Geologist Dr. K. J. V. Steenstrup, were appointed members, under the presidency of Wandel. In 1913 Steenstrup died, and new members were appointed—Captain (now Vice-Admiral) C. G. Amdrup, R.N., the professors O. B. Bøggild and H. P. Steensby and, on the death of the latter, Professor M. Vahl. As to obituary notices of the late members see M. o. G. XVI, L I.

One more remark before proceeding to mention the expeditions sent out by the commission. According to Johnstrup's plan a new map of Greenland was to be compiled, such a map being absolutely essential to future investigations, as the existing map, which dated from 1832 and was prepared from surveys and notes made by Graah, Scoresby, Giesecke, Ross, Parry, Egede, Danell, Hall, Pickergill, Gingel and van Keulen, was obviously inadequate for the purpose required; when in the following the surveys undertaken by the various expeditions are not mentioned in detail, the reason is that the development of the map of Greenland will be mentioned under the individual expeditions.

In 1876 Dr. K. J. V. Steenstrup, together with Lieut. G. Holm, R. N. and A. N. Kornerup, were commissioned to traverse a specified part of the Julianehaab District, with a view to undertaking geological and geographical researches and a reconnaissance of the margin of the inland ice.

An area of about 4000 km² was surveyed, and considerable collections of several rare minerals were brought home, while the most important old Norse ruins in the localities visited were measured and delineated; furthermore, a geological map and several excellent geological drawings were made, reconnaissances of the ice margin in the interiors of the fiords and measurings in glaciers of the motion of the ice were undertaken; however, none of the glaciers investigated made a suitable starting point for penetrating farther into the ice of the interior (M. o. G. I, II).

In 1877 Steenstrup was again sent out together with Lieut. J. A. D. Jensen R.N. Their destination was the Frederikshaab District, and the task entrusted to them was to survey the coast line of the fiords of the district and, if possible, to force their way on to the inland ice in the neighbourhood of Frederikshaab Iceblink.

Owing to difficulties which could not be foreseen and to which must be added the extremely unsettled weather conditions, the attempt of penetrating to the inland ice failed; the district was surveyed, the altitudes of the most important peaks were surveyed, collections were made of minerals, and the motion of glaciers was measured (M. o. G. I, II, VII).

In the same year the diary of Giesecke, mentioned on p. 35 was published.

In 1878 two expeditions were sent out. The one, consisting of Lieut. J. A. D. Jensen together with A. N. Kornerup and E. T. Groth, architect

and painter, had as its object the surveying of the coast from Ameralik Fiord in the Godthaab District to Tiningnertôq south of the Frederikshaab Iceblink; furthermore, it was to make one or more trips on the inland ice.

The object of the second expedition, the leader of which was K. J. V. Steenstrup, was to map the Ũmánaq District, to winter in Ũmánaq and in the course of the winter to undertake sledge journeys to the glaciers in the interior of Ũmánaq Fiord.

The former expedition investigated and surveyed the locality specified; also the ruins of the "Vesterbygd" situated in the neighbourhood of Godthaab were surveyed. A short trip on the inland ice was made, and then in the days between July 14th and August 5th the expedition penetrated 70 km on the inland ice, to the nunataqs named after Jensen, 1543 m above sea-level, the greatest height attained by the expedition. The journey, which was undertaken on ice, with deep crevasses and swiftly flowing rivers, was extremely difficult, but the experience gained of ice-travelling and the appertaining equipment was of great value, and the enterprise must be regarded as a pioneering journey, not only in these respects, but also as regards the study of the inland ice, its moraines, etc. Besides maps and instructive pictures from the ice, plants were brought home from the traversed parts as well as several rare minerals (M. o. G. I, II).

Steenstrup, the leader of the second expedition, remained in Greenland until the autumn of 1880, or very nearly two years and a half. In 1878 he mapped the east side of Svartenhuk Peninsula, traversed the interior of Nûgssuaq Peninsula and determined the motion of its glaciers. In 1879 he surveyed the west side of Svartenhuk Peninsula, investigated the sites of old Greenlandic houses and graves, while at the same time making the appertaining ethnographical collections; the two winters spent at Ũmánaq were passed in sledge journeys and investigations of the physics of the ice. In 1880 he continued his research work in the Ũmánaq Fiord, and then, together with Lieut. (now Captain) R. Hammer, R.N., he investigated the coal formation of the Vajgat and mapped the west side of Disko Island (M. o. G. II, IV, V).

In 1879 an expedition, consisting of Lieutenant J. A. D. Jensen (leader) and Lieut. R. Hammer and A. N. Kornerup, mapped the coastal territory between Kangâtsiaq and Holsteinsborg. Among other results of this journey must be mentioned Kornerup's interesting description of the geology of the localities traversed, collections of plants and minerals, a number of astronomic determinations of localities and some hydrographical investigations (M. o. G. II).

After the expedition had finished its appointed tasks Hammer went north to Jacobshavn and Claushavn in order to carry on investigations of the icefiords in that locality; he investigated the motion of the ice, the temperature conditions of the ice, of the soil and the ice-fiord, as well as the

salinity of the latter and conditions bearing upon the evaporation of the ice and the snow, which researches were carried on simultaneously with those of Steenstrup at Ũmánaq.

A map was prepared of the coastal territory of Jacobshavn as well as of Jacobshavn Icefiord and the entrance to Egedesminde, and, this being accomplished, Hammer joined Steenstrup in the above-mentioned works on Disko Island (M. o. G. I, IV).

In 1880 an expedition was sent out consisting of Lieut. G. Holm, R.N. (leader), C. L. Petersen and E. T. Groth; its object was to investigate parts of the old Norse ruins in the Julianehaab District, to continue the surveys commenced in 1876 and to get information which might serve as a guide in the projected investigation of the east coast of Greenland.

The ruins at Qaqortoq, Igaliko and Qagssiarssuk, as well as the groups of ruins at Sigssardlugtoq, at North Sermilik, etc. were investigated, drawings and topographical maps of the latter were made and several excavations undertaken, which yielded good results.

As to particulars of the east coast Holm, in the neighbourhood of Cape Farewell, was lucky to come across an umiaq crew from those parts, who were able to give information of the coast up to 64° and partly as far as lat. 66½° N. (Geogr. Tidsskr. IV. vol.). Finally, a valuable collection of phanerogams was made and taken home (M. o. G. II, VI).

In 1881 Lieut. G. Holm was again sent out together with P. L. P. Sylow, geologist, in order to map the localities between North Sermilik and Cape Farewell. Holm penetrated through the southern sounds off the east coast as far Kangerajuk in lat. 60° 14′ N., and on his return he stopped at Cape Farewell, which was thus, for the first time, visited by Europeans, and several heights were scaled. Holm gave an interesting description of the drift of the pack ice in the year 1881 and, besides the map, geological investigations were undertaken and a valuable collection of phanerogams obtained (M. o. G. VI).

In 1883 an expedition was sent out consisting of Lieut. R. Hammer (leader) the geologist Sylow and Lieut. Larsen, R.N. This expedition mapped Arveprinsens Island, Torssukátak Ice-fiord and the mainland as far as Rodebay; also the country from Christianshaab lat. 68° 45′ N., round the Sydostbugt to Egedesminde; then in a southern direction the districts as far as Kangâtsiaq. Besides this considerable survey work investigations extending over a period of three days were carried on in Jacobshavn Icefiord. Furthermore, the expedition brought back a geological map and a large collection of phanerogams (M. o. G. VIII).

In the years 1883—85 the well-known "Konebaads" (umiaq) Expedition was undertaken along the east coast of Greenland, the necessary funds being provided by the Danish Government.

The commander of this expedition, the most interesting of the enter-

prises of the commission, was Lieut. G. Holm, accompanied by Lieut. V. Garde, the Norwegian minerologist H. Knutzen, P. J. A. C. Eberlin, geologist and botanist, and two Greenlandic interpreters, Hendrik and Johan Petersen. The main object of the expedition was a continuation of the surveys and researches undertaken by Graah, if possible carrying these farther north; an accurate survey of the coast, together with archæological researches; hydrographical, magnetical and meteorological observations; investigations of the botany and geology of the country and, finally, studies of the ice, on land as well as on the sea.

The expedition arrived in Godthaab on June 14th, headed south and after a short stay at Nanortalik left, on July 23rd, for the east coast with 4 umiaqs and 10 kajaks. On the east coast at Qasingertôq provisions were deposited, and then the expedition returned to Nanortalik, the three umiaqs and most of the kajaks being sent back at once, while the remainder were kept, in order that the return journey might be utilized for solving the various tasks appointed in the instructions of the Commission; on September 15th the expedition was back at Qasingertôq, where it immediately set about building the winter house and the shed for carrying on magnetical observations, all observations being in train by October 27th.

On May 5th, 1884, the expedition left for the east coast; after a good deal of hardship it reached, on July 28th, Tingmiarmiut in lat. 62½° N.; here the members separated, Garde and Eberlin heading south in order to spend the winter at Nanortalik, while Holm, Knutzen and Johan Petersen, after having laid down a depot, went north, on July 30th, with two umiaqs. After a strenuous journey Holm and his followers, on September 1st, reached Angmagssalik, the appointed winter camp, and when the house had been built and the supplies of the expedition stowed away, Holm went north to Sermiligâq Fiord. On a small island (in lat. 65° 48′ N.), which was named after Erik the Red, a cairn was erected and the land taken possession of in the name of the King, being called Christian IX Land. On September 30th the expedition was back at Angmagssalik and went into winter quarters.

After having spent the winter here, a stay which yielded ample results, not least because of the close contact with the natives who had never seen white men, Holm went south, and on July 16th, at Ũmánaq, he met Garde, who had gone to meet him there.

The re-united expedition continued south and arrived in Nanortalik on August 18th, left Greenland on September 18th and arrived in Copenhagen on October 3rd.

At Nanortalik Garde, in the course of the winter 1884—85, had worked on with the tasks appointed to him.

The results of the expedition were surveyings and descriptions of the geography and geology of the distance travelled; an account of the manner of living of the inhabitants of Angmagssalik, their habits and anthropology;

a unique ethnographical collection from that tribe; a large botanical and geological collection; meteorological observations from Angmagssalik and Nanortalik, as well as observations of magnetism, and of auronæ and water-levels. Finally, it should be mentioned that on the east coast there was not the least trace of non-Eskimo habitation, and as the habits of the inhabitants, their manner of living and traditions did not in any way suggest an earlier intercourse with Europeans, the question of the situation of the "Österbygd" on the east coast seems to be settled for ever. (M. o. G. IX. X).

In 1884 and 1885 expeditions were sent out under the leadership of Lieut. J. A. D. Jensen, in the former year accompanied by the marine painter A. Riis Carstensen and J. T. Lorenzen, assistant at the Mineralogical Museum of Copenhagen, who, however, died on the journey to Greenland, so that Jensen had to take charge of the botanical task which had been entrusted to Lorenzen; in the second year by Lieut. (afterwards Commander) C. H. Ryder, R.N. and S. Hansen, anthropologist.

During these years investigations and surveys were undertaken of the west coast from lat. 64 to 67° N.; short trips on the inland ice were made in various places, with investigations of the vegetation of the nunataqs encountered. Itivdleq Fiord and Qáqatsiaq are identified with the localities, which by Hall were named Christian IV's Fiord and Mount Cunningham; the water of salt lakes was investigated; measurings of temperatures were undertaken in the fiords, proving the existence of a bottom-layer of a negative temperature in Sermilik Fiord; groups of ruins in the districts of Godthaab Fiord and Ameralik Fiord were investigated and surveyed; lists were made of the longitudes and latitudes of geographical positions; minerals and rocks, among others, olivine rocks, were brought back, as well as a large collection of phanerogams (M. o. G. VIII).

In 1886—87 an expedition was sent out to the Upernivik District. It was commanded by Lieut. Ryder, and the other members were Lieut. J. C. D. Block, R.N. and N. V. Ussing, mineralogist, who returned in the autumn of 1886.

In spite of inclement weather conditions the expedition succeeded in surveying the coast land with the interiors of the fiords, and in determining the margin of the inland ice from lat. 72° to 74½° N., the motion of the ice, its character, temperature, etc. particularly in the glaciers at the head of the Upernivik Icefiord; house sites and graves were examined and ethnographical specimens collected; soundings were taken in the fiords, indicating curious stratifications of the water layers; anthropological measurings were made; furthermore, the winter was spent in sledge-journeys and in meteorological and magnetic observations, while an accurate astronomical determination was obtained of the longitude and latitude of Upernivik. The lowest temperature registered was —40° C.

Ussing brought home a valuable collection of minerals, phanerogams, lichens and algæ.

As a valuable collection of minerals had been lost in the fire destroying Christiansborg Castle, the Commission in 1888 sent out K. J. V. Steenstrup to the Godthaab and Julianehaab Districts with the object of trying to replace what had been lost. Besides this task Steenstrup had been intrusted with the conduct of the first large eudalyte collection for the Cryolite Company at Kangerdluarssuk, and he succeeded in collecting about 16,000 kg of impure substance, as well as in obtaining a large collection of minerals from the area traversed.

Kolderup-Rosęnvinge who accompanied him, made a considerable collection of phanerogams and algæ, several of which were new; more particularly he studied the birch and willow shrubs, and partly on the strength of earlier observations, partly on the strength of his own he gave a description of the vegetation of South Greenland (M. o. G. XIV, XII).

In 1888 S. Hansen, anthropologist and physician, traversed the districts round Ũmánaq Fiord and Disko Fiord, in order to continue and complete the studies, begun in 1885, of the anthropology of the West Greenlanders. The results of this journey, which do not lend themselves to a short summary, are to be found in M. o. G. VII.

In 1889 and 1890 W. Lundbeck, B.Sc. was sent out, in 1889 accompanied by N. Hartz, B.Sc. and in 1890 also by Professor Bergendal from Lund, with the object of observing the Greenland insect fauna and making collections of the same. In the former year the Godthaab, Frederikshaab and Julianehaab Districts were traversed, both journeys yielding ample results towards the knowledge of insects and, furthermore, a considerable collection of phanerogams, fungi, lichens, algæ and plant-fossils. The object of Bergendal was the study of certain forms of marine animals (M. o. G. VII).

In 1890 Lieut. Block was sent out, accompanied by H. I. Lassen, geographer. The coast land from Tigssaluk to Julianehaab was surveyed, while five days were spent in observations of the glacier debouching into the Sermitsialik Fiord, the only active glacier of importance between Ivigtût and Julianehaab; at the same time three series of soundings were made across the fiord with determinations of temperature and salinity. A large collection of algæ and vascular plants were brought home (M. o. G. VII).

In 1890 Parliament made the necessary grants towards an expedition to the east coast of Greenland. The expedition was called The East Greenland Expedition, and it started for its destination in its own ship, under the command of Lieut. Ryder. The other members were Lieut. H. Vedel, R.N.; E. Bay, zoologist and geologist; N. Hartz, botanist; H. Deichmann, entomologist and physician, and the interpreter Johan Petersen.

The main object of the expedition was the survey and investigation of the east coast from lat. 66° to 73° N., a continuation of Holm's expedition in 1883—85.

The sealing vessel "Hekla" was chartered for the passage and landed at Cape Stewart with an equipment consisting of boats, provisions, house, instruments, etc. The expedition was to investigate the distance from lat. 70° to 73° N. to the widest possible extent, partly unassisted and partly with the help of the vessel and the steam launch, which had been brought for the purpose. After the departure of the "Hekla" investigations were to be carried on in the course of the winter 1891—92, with the winter quarters as their starting point, and in the summer of 1892 the unknown coast from lat. 70° to 66° N. was to be investigated by a boat-expedition.

If the latter, when reaching Angmagssalik, should prove unable to get into touch with the vessel, which after having fetched the members of the expedition in the autumn of 1892 was to call at Angmagssalik, and so was forced to winter in that place, it should attempt to reach the Julianehaab District in the course of the following summer and return from there by one of the vessels of the Royal Greenland Trading Company.

On June 7th, 1890, the expedition left Copenhagen, reached the pack on June 20th in lat. 68° 12′ N. and long. 13° 5′ W., followed the margin of the latter as far as lat. 76° N., when it headed south-west, and on July 20th it succeeded in landing at Cape Broer Ruys; from there the course was shaped along the coast, but not until August 2nd did the expedition reach Scoresby Sound. Ice conditions, however, did not permit of landing at Cape Stewart, and after several fruitless attempts Ryder resolved to go into winter quarters in the already visited Hekla Harbour, and to keep the ship during the winter, in order to be more certain of getting out in time the following year, so as to be able to reach Cape Brewster, where the expedition was then to be landed. Dwelling house, observatories and provision sheds were erected in the neighbourhood of the harbour, and on September 15th the expedition was installed on land.

Before, as well as after the closing in of the arctic winter, Scoresby Sound was surveyed with all the islands and fiords situated within it, and all investigations and observations were carried out according to the programme.

On August 8th, 1891, the "Hekla" left her winter harbour and headed out of the fiord. After having laid down a depot of provisions and munitions at Cape Steward the "Hekla" shaped her course along the coast towards Cape Grivet, but owing to unfavourable ice conditions and lack of coal, Ryder decided to go to Dyrefiord on Iceland in order to replenish his coal supply.

After having finished coaling the "Hekla" left Dyrefiord on August 29th, heading for Cape Grivet, as Ryder wanted to make an attempt to reach land in this place and then follow the coast in a southern direction with the object of getting to Angmagssalik, either with the vessel or by means of a boat. However, the ice formed a broad and solid belt along the coast, and storms with snow were raging all the time, so the only chance of accomplish-

ing anything in the course of the autumn was to try to reach Angmagssalik as soon as possible.

On September 10th the "Hekla" anchored in Tasiussaq Harbour, from where Ryder with 2 boats went along the coast inside the skerries as far as Amagâq Island, from where he returned to Angmagssalik, after a fairly large collection of ethnography had been made; the "Hekla" left Tasiussaq Harbour on September 26th, and arrived at Copenhagen on October 12th.

Even though the expedition had not been able to carry out its programme to the full, the results obtained were good, *viz.* the survey of coast stretches and Scoresby Sound, with the whole complex of islands and fiords situated within the latter; magnetical, astronomical and meteorological observations; hydrographic researches, zoological, botanical and geological collections; observations of the ice and, finally, observations and collections of ethnography (M. o. G. XVII—XIX).

In 1890 M. Traustedt, B. Sc. was sent out with a view to investigating the fauna of Disko Bay. An ample collection, particularly of lower animals, was brought home together with fossil plants from the Cretaceous and Tertiary formations.

In 1893 an expedition was sent out, consisting of Lieutenants V. Garde and C. Moltke, R. N. The object of this expedition was the survey of that part of the Julianehaab District which had not been mapped in 1890, *viz.* Nunarssuit with its environs, and the charting and investigation of a passage through Torssukátak in an eastern direction towards Julianehaab, as well as of the harbours and anchoring places along this coast.

In connection with this work the expedition was to carry out magnetical and hydrographical investigations and, time and weather permitting, to attempt to penetrate to the inland ice.

On April 24th it arrived in Frederikshaab; from April 29th to May 7th a boat trip was undertaken to the outpost Avigait, with the object of investigating some emergency harbours along this distance; from May 12th to 17th the journey to Arsuk was made; from May 23rd to June 12th some surveys were undertaken, and on June 14th everything was ready for the journey along the inland ice. The place chosen for the ascent was the region round Sermitsialik Glacier, and after sledges and provisions had been transported up on the inland ice, with the assistance of the Greenlanders, Garde and Moltke continued on the inland ice. On June 23rd the expedition had reached a place 110 km from the starting point and an altitude of 2286 m; as half of the time which could be spent in the journey had elapsed and the route had failed to offer features of particular interest, it was resolved to leave for home along a more southerly but somewhat longer route, past a nunataq, Aputainuitsoq, which Steenstrup had charted by means of sights taken from the coast station in 1877. The progress of the expedition being hampered by continuous snow storms it only reached the nunataq on June

26th. It proved to be a complex of small nunataqs with no traces of animal or vegetable life, and after having examined the surrounding ice the expedition returned to the starting point, which it reached on June 29th.

As the surface conditions encountered on this expedition were quite different from those met with on Jensen's Expedition in 1878, especially by the absence of the many deep crevasses, this journey yields interesting information of the physics of the inland ice in South Greenland (M. o. G. XVI).

This being done the expedition in good earnest set about its principal task, *viz.* the survey of sailing courses and harbours along the distance, about 130 km, from the western mouth of Torssukátak as far as Julianehaab, which work was executed together with some observations of declinations and measurings of the temperature of sea water.

In 1894 an expedition was sent out under C. Moltke, accompanied by Lieut. F. B. Petersen, R.N. and A. H. Jessen, geologist.

The object of this expedition was to undertake geological and geographical research work along the coast from Julianehaab to Nanortalik, as well as in the southern archipelago Kitsigsut, and the mapping of the distance covered; furthermore, it was desired that the expedition should investigate North Sermilik Glacier and obtain profiles with corresponding determinations of the temperature and salinity at the mouths of the fiord; determinations of variation and geological and botanical collections.

On April 13th the investigations were begun from Julianehaab in a southern direction, being continued until June 12th, when the ascent was made to North Sermilik Glacier; after having completed its investigations in those localities the expedition started its hydrographic researches in the Sermilik and Ikerssuaq Fiords, and in July the survey of the coast was continued, being completed in the early part of September.

The results of the expedition were a map of the above-mentioned coast stretches, thorough investigations made during a five days' stay at the Sermilik Glacier and the inland ice, up to 4 km west of the latter; interesting hydrographic researches from the above-mentioned fiords; magnetic observations, geological observations and collections, with a geological map of part of Julianehaab District; botanical collections from the skerry-fence, among which several very rare specimens (M. o. G. XVI).

In the same year Lieut. Daniel Bruun was sent out as the leader of an archæological expedition to the Julianehaab District; in the instructions prepared by the second department of the National Museum, special importance was attached to the solving of the problem of the individual houses among the ruins of the old Norse farmsteads.

Pursuant to the instructions excavations were made in several places, as for instance, in the old farmstead of Erik the Red, Brattahlíð, in Eriksfiord (now Tunugdliarfik), in the bishop's see Garðar (now Igaliko) with

the ruins of the old cruciform church; further, at Qagssiarssuk in Igaliko Fiord (eastern branch), where the farmstead Höfði was situated, in the ruins of a large old Norse farmstead at Tasiussaq, a bay from Sermilik (Isafjörðr), and at Tunuarmiut in Tunugdliarfik. At the same time map sketches were made, whenever the opportunity occurred, of groups of hitherto unknown ruins. Independent investigations, forming part of the work of the expedition, were carried on in the fiords south of Igaliko Fiord by Lieut. Frode Petersen, R. N.

By means of these investigations the expedition succeeded in separating the individual buildings of the farmsteads, and especially it became possible, for the first time, to locate the dwelling houses, which proved to be of a pronouncedly Icelandic type. It was possible to distinguish the various houses, etc., and upon the whole it became evident that the old Norse settlers of Greenland had arranged their existence in complete agreement with what it had been in the regions from which they came.

By excavations of the middens and refuse heaps, which the expedition also succeeded in locating, it was proved that the old Norsemen had kept horses, cows, goats, sheep and dogs, and that they had further practised very considerable sealing and hunting of game. That fishing had played a considerable part did not, it is true, appear directly from the find of bones, but indirectly from the presence of a great number of sinkers for fishing nets.

Beyond those which were already known, no churches were found in the localities investigated, but part of the churchyard at Qagssiarssuk in Igaliko Fiord (eastern branch) was excavated; here a number of skulls were found, and the principal church at Igaliko, since destroyed, was surveyed.

By the excavations undertaken a number of antiquities were brought to light, particularly utensils manufactured of soapstone, but also articles made of iron, such as keys and nails; further, articles of bone, pieces for various games, spinning stones, etc. Several of the soapstone articles had marks graven into them, in some cases also runic characters; only a few of them were ornamented with Roman designs, and upon the whole the objects found bore evidence of a low artistic standard (M. o. G. XVI).

Further, in the same year the Commission sent out the Swedish mineralogist G. Flink who had offered to undertake mineralogical collections in the Julianehaab District. The commission had been glad to avail itself of this offer, so as to extend the knowledge of occurring minerals and thus to create a wider basis for subsequent geological researches. The localities investigated were Kangerdluarssuk and Narssârssuk, and the expectations entertained of the work of this excellent collector were, if anything, surpassed.

Besides the known minerals, which were collected and supplemented earlier finds, a number of new ones were found and in such quantities that they might be made the object of thorough investigation (M. o. G. XVI and XXIV).

In 1898 an expedition was sent out, consisting of K. J. V. Steenstrup (leader), Morten Pedersen Porsild, B. Sc., botanist, and the painter Harald Moltke.

Apart from botanical researches the object of this expedition was to travel along the south and north-east coast of Disko, with the object of studying ice conditions in that island, and particularly whether there were any valleys, free of ice, passing through greater parts of the island.

On the passage to and from his destination Steenstrup carried out investigations regarding the colour of the sea water, and whether it was possible, by means of simultaneously taken samples of plankton, to judge about the possible influence on the colour of the kind and quantity of plankton.

On June 30th the investigations along the east coast of Disko were begun, past the Mudder Bay, with longer stays in several places of the valleys, especially in Kûgánguaq Valley at the Vajgat. The return journey took place along the same route, and on August 12th the expedition was back at Godhavn, from where the investigations were continued on the south and west coast of Disko and up to Mellemfiord, with a prolonged stay in Disko Fiord. On September 26th the expedition left for Copenhagen.

The result of the journey was a systematic survey of the geology of the distance travelled and its valleys, the issue being that all the latter are closed at their heads by glaciers from the ice-covered plateau of the interior; further, ample botanical collections and a number of pictures by Moltke, including a water colour sketch of the north side of the Vajgat, from Niaqornârssuk to Atanikerdluk (M. o. G. XXIV, with accompanying illustrations and XXV).

The surveying and mapping of the whole of the west coast of Greenland, south of Alison Bay, being now completed, the first care and concern of the Commission was the investigation of the east coast from lat. 66° W. to Scoresby Sound, and not least because the attention abroad, on several occasions, had been directed towards this locality in such a manner that it was to be feared that the initiative of such an investigation would be taken elsewhere.

Fortunately the amount required for the accomplishment of this task, *viz.* 150,000 kroner, was placed at the disposal of the Commission by the Carlsberg-Fund, and preparations could be made for carrying out the projected expedition. The outlines of the plan were the following: Lieut. (now Vice-admiral) G. C. Amdrup, R.N. the appointed leader of the expedition, with the object of becoming acquainted with conditions along the east coast, was to spend a year in the Angmagssalik District, where in 1894 a mission and trading station had been established; then in the following year, after a winter spent in Denmark, he was to start with the remainder of the expedition for Scoresby Sound, and from there to go south with Angmagssalik as his final destination.

The enterprise was called "The Carlsberg Fund Expedition to the East Coast of Greenland," and the members of the first part of the expedition (the journey to Angmagssalik in 1898) were, besides the leader, Ch. Kruuse, B. Sc., botanist; K. Poulsen, physician; petty officer A. Jacobsen; and S. P. Nielsen, mechanic and sailor.

The main object of the preliminary expedition was the laying out of depots, partly for the journeys undertaken during the stay at Angmagssalik, and particularly one, at Kangerdluarsuk, for the projected expedition from the north.

Amdrup and his companions arrived in Angmagssalik on August 31st, 1898, and immediately started preparations for the arrangement of the winter quarters; a boat journey was undertaken in a northerly direction, as far as lat. 66¼° N., and the following winter was spent in meteorological, magnetical and astronomical observations, in studies of the life of the natives, and, finally, two sledge journeys, the longest of which, in a northern direction, extended as far as 66¼° N. lat.

On June 21st, 1899, the boat journey began, the object of which was the laying out of provisions at Kangerdluarssuk. The expedition, however, did not succeed in reaching this fiord, for at Agga Island all progress was stopped by impenetrable masses of ice. On the peninsula of Nûalik, situated a little to the south of Kangerdluarssuk, the provisions were deposited, a cairn was built, and possession taken of the country in the name of the King of Denmark; another depot had already been laid down in lat. 66° 07′ N. Everywhere along the distance travelled there were traces of former habitation, and at Nûalik the expedition found the ruins of a large house, the "dead men's house" with the remains of 30—40 bodies; everything seemed to point in the direction that the catastrophe which had taken place here was of a comparatively recent date.

On August 18th the expedition started on its return journey, leaving Greenland on September 3rd, 1899.

Besides the knowledge obtained of the coast and ice conditions off the latter, the results of the expedition were a map of the travelled distance, as well as scientific collections and observations. (M. o. G. XXVII).

In 1899 K. J. V. Steenstrup and A. Theilgaard were sent out to the Julianehaab District with the object of carrying on geological researches and more particularly of collecting eudialyte for the Cryolite Company.

The results of this expedition were 44,000 kg of impure eudialyte, a detailed investigation of the red sand stone occurring in Igaliko and Tunugdliarfik Fiord, and an interesting examination of some old Norse ruins of the district, especially the Qaqortoq Church. (M. o. G. XXXIV).

In 1900 the Carlsberg Fund Expedition to East Greenland, which had been commenced in 1898, was completed.

The expedition which, as already mentioned, was to be commanded by

Lieut. Amdrup, had secured the arctic vessel, "Antarctic," and consisted of the following members: N. Hartz and Ch. Kruuse, botanists; H. Deichmann, physician and geologist; S. Jensen, zoologist; Dr. O. Nordenskiöld, geologist; Lieut. J. P. Koch, geodetist; the artist E. Ditlevsen; petty officer R. N. A. Jacobsen; sailor and mechanic S. Nielsen and Ejnar Mikkelsen, the three latter being elected for the expedition along the coast, and, finally, the men and officers of the ship, the first officer, V. Kjøller, being a mate in the Royal Greenland Trading Company.

The tasks of the expedition were the following:

1) To land Amdrup with his companions in lat. 69° N. approximately, possibly somewhat farther north.

2) To carry on scientific investigations in the regions round Scoresby Sound, in Davy Sound and Franz Joseph Fiord; during the stay in Scoresby Sound Ryder's depot at Cape Stewart should be overhauled and completed.

3) To undertake scientific researches in the Angmagssalik District.

In Amdrup's absence the leadership of the expedition was to be taken over by Hartz, while the command of the ship was to pass to the first officer Kjøller.

On June 14th the expedition left Copenhagen. On June 26th the "Antarctic" anchored in the Drivtömmer Bay on the south of Jan Mayen, where the expedition landed and remained for two days. On June 29th the ice off the east coast of Greenland was entered in lat. 71° 03′ N., long. 9° 32′ W. The ice proved impassable; so the expedition was forced to head north, and on July 11th it reached the coast at Little Pendulum Island. Under considerable difficulties the "Antarctic" headed south, reached Cape Dalton on July 18th, where the boat expedition was landed, and then again headed south on July 22nd, after having erected a house and arranged about the supply of provisions, which the boat expedition might fall back upon if it should fail to reach its destination.

The journey was undertaken in a boat, 5.6 m in length and 1.4 m wide, with a freight of 1659 kg and 0.26 m of freeboard; on September 2nd the expedition arrived at Angmagssalik, after having made about 1000 km and experienced many dangers among the icebergs and ice floes of the arctic sea, with pressure ridges and rapids and almost constant fogs, which forced the four men to haul up the boat on ice floes, in order to save their lives, with dangerous landings and generally thorough winter weather. Along the traversed and charted distance, landings were made on several occasions, with good scientific results, particularly in ethnography, by the examination of Eskimo graves.

Possession was taken of the travelled distance, which was called by the name of Christian IX Land.

On July 21st the "Antarctic" left Cape Dalton, headed north, and after several stays along the coast entered Scoresby Sound, where it lay at anchor

in Hurry Inlet from August 1st to the 10th, during which period the scientific staff made many excursions. After a visit in the Northeast Bay and a renewed stay in Hurry Inlet, the "Antarctic" left with the view of mapping the coast from Cape Stewart to Davy Sound, in the course of which work landings were made in several places. The stay on the east coast was wound up by a visit to Forsblad Fiord, and on September 2nd the "Antarctic" left the east coast for Dyrefiord on Iceland in order to take in coals.

On September 7th the ship expedition left Dyrefiord and arrived in Angmagssalik on September 11th, where to its great joy it found the boat expedition; on September 17th the united parties left Greenland and arrived at Copenhagen on October 4th.

The results of the ship expedition were very large from the point of view of geology, zoology and botany. Upon the whole the Carlsberg Fund Expedition to East Greenland was carried out in close agreement with the programme, and by the carefully elaborated and executed plan, by the close attention even to the minutest details of preparation and equipment, it stands as a model of all arctic expeditions (M. o. G. XXVII—XXX and partly in XXIX and XLIX).

In 1900 the Commission sent out N. V. Ussing, accompanied by O. B. Bøggild, to the environs of Tunugdliarfik Fiord in the Julianehaab District, with the object of examining the eruptive rocks younger than the red sandstone of that locality; furthermore, if time permitted, they were to investigate the nepheline rocks at Ivigtut. In 1908 Ussing was sent up once more, accompanied by J. Helveg, engineer, in order to investigate the tracts between Julianehaab and Ivigtût, particularly with a view to the occurrence of copper.

Professor Ussing died in 1911, but on his death the reports of these two journeys were ready for publication, being subsequently published by his companion and successor, O. B. Bøggild, in the thirty-eighth volume of "Meddelelser om Grønland," an interesting description of the geology of the environs of Julianehaab, with a detailed account of the voyage of research in 1900. The volume is accompanied by four geological maps.

In 1900 the Commission further sent out W. Thalbitzer, M.A., with the object of studying the language and folklore of the Greenlanders. Thalbitzer spent the winter in the southern and innermost districts of Disko Bay and in Ũmánaq Fiord, after a sledge journey across the Nûgssuaq Peninsula. In the course of the winter he went about by dog-sledge, covering a total distance of about 1500 km, in order to visit the natives in their huts. For five months he lived among them, becoming personally acquainted with them under all conditions. In the course of the summer of 1901 he went by sea as far as Upernivik, from where he returned to Copenhagen. On his journey, from which he brought back a considerable linguistic and folkloristic material, he learned to understand and to speak the Eskimo language.

For the first time the phonetic character of the Eskimo language, particularly as regards the North Greenland dialects, was subjected to investigation according to the modern descriptive method instituted by Professor Otto Jespersen. Within the same area there were, further, a number of old legends, nursery rhymes, songs and drum songs. Names of localities and persons were written down and, furthermore, Thalbitzer, by means of his violin, noted down a great number of dancing and singing melodies from older and more recent times. The greater part of this material was treated in "A Phonetical Study of the Eskimo Language,"[1] the chief part of which is a phonetical description followed by a comparative study of the hitherto unknown or little known dialects in the districts between Davis Strait and Bering Strait. (M. o. G. XXXL).

In 1901 Dr. H. Deichmann was sent out with the object of undertaking bacteriological researches and studies in the Holsteinsborg and Godthaab Districts, in continuation of researches begun on the expedition to East Greenland in 1900.

With the support of the Carlsberg Fund C. Kruuse in 1901—1902 undertook the carrying out of botanical and ethnographical investigations at Angmagssalik. His stay was to extend over a year, and besides the above-mentioned investigations he was to carry out such scientific researches as time and conditions permitted. Kruuse, who had been with Amdrup during his stay at Angmagssalik in 1898—99, and had subsequently joined the Expedition of 1900, was well acquainted with the region, and the expedition was carried out according to the programme. The vegetation of the coast was investigated in a northern direction as far as the peninsula Akiliaruseq, chief importance being attached to the Angmagssalik District proper. The results of the journey were facts relating to the conditions and the diversity of the vegetation. Furthermore, zoological and geological collections were made, as well as studies on ethnology, among which a collection of drum songs (M. o. G. XXV and XLIX).

In the summer of 1902 Dr. (now Professor) A. Krogh joined Porsild in a journey of botanical research round Disko Island. This journey was undertaken by umiaq, and in its course a series of analyses were made of athmospheric conditions, as well as determinations of the tension of carbonic acid in natural waters, supplemented by a series of determinations of samples of ocean water taken from one of the Greenland vessels on its return journey. The results of these investigations are to be found in two treatises in "Meddelelser om Grønland," the former partly indicating methods for the determination of the tension of carbonic acid in water and elucidating

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[1] In an article on the North American languages in "The American Anthropologist" (1914 p. 586) P. E. Goddard writes of Thalbitzer's investigations: "He has published the first phonetically adequate treatment of any American language, if not of any non-literary language anywhere."

the relation between its quantity and tension in sea water, partly dealing with the tension in various—Greenlandic and Danish—water samples, and their importance from the point of view of geology and biology.

In the second treatise the analyses of the atmosphere are given, their technique according to later investigations having proved less certain, so that the range of the variations observed must now be considered extremely doubtful; further, a disquisition on the cause of changes in the percentage of carbonic acid in the atmosphere and the interchange of atmospheric and oceanic carbonic acid, by means of which the ocean becomes the regulator of the atmosphere, effectively counteracting any change in the percentage of carbonic acid (M. o. G. XXVII).

In 1902 M. C. Engell, Ph.D. was sent out together with Lieut. H. V. Schjørring. The object of this expedition was, besides various geological tasks, to continue the investigation carried on in 1879—80 by Hammer in the environs of Jacobshavn Icefiord and, further, in accordance with the resolutions of the International Glacier Commission, to demonstrate the changes which had taken place within the past few years; to obtain this end a set of triangles was to be laid down and cairns erected, from which present as well as future surveying could be undertaken.

The result of the glaciological researches of the expedition (as to details of the latter see "Meddelelser om Grønland") was that the glacier at Jacobshavn Icefiord had receded considerably since 1880; furthermore, observations were undertaken of the ice margin towards the south, particularly in Orpigssuit Fiord; the uplift of the land was proved by raised beaches, and the vegetation conditions in localities from where the ice had receded were studied.

A detailed description of the triangulation undertaken by Schjørring is to be found in M. o. G. XXVI.

In 1903 Daniel Bruun was sent out in order to continue the investigations of the old Norse ruins, which had been commenced in 1894, this time in the Godthaab and Frederikshaab District; the amount which had been granted for the journey did not include excavations.

Bruun traversed parts of Godthaab and Ameralik Fiords, with their inner ramifications, on part of the journey accompanied by Inspector Bendixen; the presence of a number of new groups of ruins was proved, and from the total number it appeared that the chief part of the Vesterbygd had been situated here. A little excavation work was undertaken at the head of Ameragdla at Qilaussarfik, where there was a church with the appertaining churchyard, by which excavation the skeletons of five Norsemen were brought to light. The farmstead was perhaps identical with the farmstead in Lysefiord, in which the son of Erik the Red, Thorsteinn, died in 1001; as appears from the saga, no church had as yet been built in that place at the time of his death.

Particularly at Ameragdla ruins were found of a great number of old Norse farmsteads, in the home fields of which there is still a luxuriant vegetation, which partly covers the houses; in many places the latter were, however, clearly distinguishable, and, for instance, the stones indicating stalls were still frequently visible. On the other hand, the dwellings had collapsed and were overgrown with vegetation, being to a very large extent built of turf, as stones suitable for building purposes were lacking in those parts.

The skerry-fence off Godthaab Fiord was visited, and here Bruun succeeded in finding the first dwelling of Hans Egede, situated on an island north of the trading post Kangeq, in extremely bleak and desolate surroundings. Then Brunn went on to Ivigtût, and in the five fiords immediately north and south of Arsuk Fiord, the latter being included in the number, 18 Norse farmsteads were identified, seven of which had already been described at greater or shorter length. These ruins evidently formed the northern district of the Österbygd, the northern boundary being at Tigssaluk. Between this place and the mouth of Ameralik Fiord, south of Godthaab, there is a distance of 211—256 km, according as the journey is undertaken in a straight line or following the coast, and with the exception of a few, less considerable groups of ruins the latter tract was practically uninhabited at the time of the old Norsemen. Consequently, the southern boundary of the Vesterbygd must be approximately put at Ameralik Fiord, as according to old accounts the distance from the Vesterbygd to the Österbygd should be six days' rowing, which agrees with the distances here. Otherwise, the identification of the extent of the Vesterbygd in a northern and southern direction is still doubtful. (M. o. G. V. LVI).

In 1903 Dr. Engell was sent out again with the object of continuing the glacialogical researches undertaken in 1902 at Jacobshavn Icefiord and its environs; as to the results of these researches see M. o. G. XXXIV. Furthermore, observations were made of the botany, geology and meteorology of the localities traversed.

In 1904 Thalbitzer was sent out to Angmagssalik with the object of continuing the studies of the Greenland language and folklore, begun on the west coast in 1901—02.

At this settlement, which had only been established in 1894, he came into contact with a fairly untouched, in part still heathen Eskimo population, and he received a strong impression of the primitive original Eskimo culture of Greenland; the greatly deviating dialect of that locality was studied; and partly by means of the phonograph he succeeded in noting down a great number of popular legends, accounts, old fashioned poems of all kinds, charms, drum songs, etc., and also in other respects he obtained information of the original culture of the isolated tribe, its religion and social habits.

The main results of this research work were published in 1914, but already in 1911 a disquisition appeared on the music of the Eskimos, noted down at Angmagssalik, partly by means of a phonograph, and transcribed in Copenhagen by the musical historian, Hjalmar Thuren, in collaboration with Thalbitzer. The phonographic records, about 60 in all, were cast in bronze, the expenses being defrayed by the Carlsberg-Fund, and deposited in the folklore collection of the Royal Library of Copenhagen (M. o. G. XL).

After his return, in 1906, Thalbitzer undertook the task entrusted to him by the Greenland Commission and the Carlsberg Fund, *viz.* to prepare a description of the ethnological collections from East Greenland, and first and foremost the collections brought home by the Amdrup Expedition. In 1909 he published his description of the northermost finds, *viz.* from the now extinct dwelling places north of Angmagssalik between lat. 68° and 75° N. (M. o. G. XXVIII).

In 1914 Thalbitzer published a description of the extinct Angmagssalik tribes which had migrated in a northern direction, and whose furniture, weapons, ornaments etc. were found by Amdrup at the "dead men's house" in the peninsula Nûalik north of Kialuneq. This description together with a new edition in English of G. Holm's "Ethnologisk Skitse of Angmagssalikerne" (M. f. G. X) has been worked up into a detailed description of the ethnographical collections of Angmagssalik (M. o. G. XXXIX).

In 1906 Ad. S. Jensen and Poul Harder were sent out in order to investigate the raised marine layers at Sydost Bay.

This expedition, which arrived in Egedesminde on June 15th, visited Orpigssuit, Qarajak, Sarfarssuit, Akugdlît, Marraq, Christianshaab and Ler Bay; finally, Jensen carried on marine dredgings at Jacobshavn, whereas Harder travelled through Blæse Valley. The expedition left Greenland on September 9th.

The object of the expedition was, through an investigation of raised marine deposits and their fauna, to elucidate the latest geological history of the localities traversed, with a view to changes in the climate and changes of levels. The investigation of fossil deposits at the fiords east of Sydost Bay yielded good results, which were later on supplemented by observations from the large clayey plains on the south side of Sydost Bay and south of Claushavn. As main results can be mentioned:

At a period close to the present day the level of the regions round Disko Bay was about 100 m lower than at present; from the large extent and considerable thickness of the deposits of clay, formed at that time, it appears that this period of subsidence has been comparatively protracted, while its fossil contents indicate a high-arctic climate.

Of the time preceding this subsidence only little is known with certainty; the level of the land was somewhat higher, though not so high as at present, and for some time the climate seems to have been milder, rather as at the

present day. In the course of the period following upon the great depression the land has slowly risen to its present level; at the same time the climate has become milder, there having been a temperature maximum during the latter part of the uplift. The first traces of the boreal bivalves, which indicate a climate warmer than that of the present day, were found in shore-formations at levels of 30—35 m, but they occur most abundantly in a shore deposit, which only reaches 10 m above sea level. The occurrence of river deposits over marine layers, under very peculiar conditions, indicates a smaller advance of the margin of the inland ice, at a period immediately preceding the above-mentioned warmer period[1].

In 1907, by the wish of the Royal Greenland Trading Company, Lieut. J. T. Borg, R.N., was sent out to survey Faltings Harbour in Godthaab Fiord as well as Nûgssuaq Harbour in the Ũmânaq District, and also to inspect cairns and sea-marks, and this survey he continued in 1908 in the tracts between Godthaab and Skinderhvalen and some of the fairways to Godthaab.

In the same year Professor Ussing was sent out, accompanied by Helweg, in order to continue the investigations undertaken by him in 1900, his attention being particularly directed towards the occurrence of copper. As to the result of this journey see page 126.

In 1909 H. P. Steensby and Thomas Thomsen, of the National Museum at Copenhagen, were sent out to Disko Bay and the Cape York District, to which they were brought by the steamer "Godthaab," together with the expedition which, under the leadership of Knud Rasmussen, was to establish the mission station "Nordstjernen." Steensby made ethnographical and anthropological studies in the two localities mentioned (M. o. G. XXXIV and L), whereas Thomsen in Disko Bay undertook excavations, for instance, in the Sermilik dwelling place and among the Polar Eskimos where he purchased objects to be incorporated in the ethnographical collection of the National Museum.

In the same year A. Krogh and his wife, the physician Maria Krogh, visited the biological station on Disko Island, where they carried on investigations of the nutrition of the Greenlanders as well as experiments of respiratory metabolism, each experiment extending over a period of 3—4 days and being made with two Greenlanders at a time. The numerous samples of food, urine and excrements were conserved, and the quantitative determinations of the latter were undertaken by the Nutrition Laboratory, Boston.

Based on the statistical researches of Rink, a calculation was undertaken of the normal daily fare of the Eskimos and its percentage of the most im-

[1] Ad. Jensen and Poul Harder: "Postglacial Changes of Climate in Arctic Regions" in "Die Veränderungen des Klimas seit dem Maximum der letzten Eiszeit." Stochholm 1910.

portant constituents of food; it was found to certain very large amounts of protein (280 gr) and an extremely small amount of carbo-hydrate. The low carbo-hydrate percentage is essentially due to the amount of glycogene contained in meat. The food of the Eskimos thus bears a striking resemblance to that of the typical carnivorous animals, and their habits as regards the taking of food also greatly resemble those of the latter. The food experiments showed that the great amount of protein matter is turned to excellent account in the intestines of the Eskimos and that it does not, to any considerable extent, raise the basal metabolism, as is the case in organisms unaccustomed to large amounts of protein. Any detrimental effects of this almost exclusive meat diet have not been traced.

In 1909 and 1910 Lieut. Borg was sent out with the object of carrying on the coast survey, begun by him in 1907 and 1908, and further to measure the Kobbermine Bay and the bay from Torssukátak to Nyeboes Channel and several harbours, all in the interest of navigation.

In 1909 Dr. J. P. J. Ravn and Dr. A. Heim from Zürich were sent out, with the object of carrying out geological researches of the carboniferous formations on Disko Island and Nûgssuaq Peninsula, Dr. Heim being more particularly entrusted with the task of investigating the coal and graphite layers for practical purposes.

The carboniferous layers on the south-east and north-east coast of Disko, as well as on the south-east and north-east coast of Nûgssuaq Peninsula, were investigated, with interesting results from the point of view of geology, mineralogy and palæontology. Besides the report of these investigations written by Ravn, there is another report by Hein dealing with the petrography and geology of the north side of Nûgssuaq Peninsula, the latter accompanied by excellent photographs (M. o. G. XLVII).

In 1909 the architect M. Clemmensen was sent out with the object of investigating church ruins from the old Norse period, in particular the ruins of Qaqortoq, several problems bearing upon the latter being set forth in the instructions given by the Commission.

Clemmensen first visited the Qaqortoq ruin, which was accurately surveyed in all directions, while photographs were taken of all the walls, from the inside as well as from the outside; a detailed investigation was undertaken of the manner of building and the material used, and it was proved that lime had been employed in cementing the walls, inside as well as outside; a number of excavations were undertaken along the walls, and though frequent excavations had been made within the church, Clemmensen succeeded in finding the highly decomposed remains of a wooden coffin with a few human bones. Finally, it was investigated what could be done towards preserving the ruin.

From Qaqortoq Clemmensen went to Tunugdliarfik and Igaliko Fiord, where several groups of ruins were investigated, with a view to tracing,

if possible, some of the still unidentified church ruins from the Norse period. According to the old accounts there were in all twelve churches in the Österbygd, of which only five had been found, nor was any positive result obtained by the investigation of Clemmensen in this respect. The Church ruins at the old Brattahlið, Igaliko and Qagssiarssuq were visited and the plan of future excavations drawn up.

Mention should, further, be made of an excursion to Ujaragtarfik Island, with the object of trying to find the place where, according to tradition, the old Norse settlers had found lime, but without any result (M. o. G. XLVII).

In 1911 Dr.V. Nordmann, accompanied by his wife, was sent out to North Strømfiord in order to investigate the changes in the fauna from its mouth to its head, where the glacial river debouches into it; furthermore, researches were to be made of the fauna in Giesecke's Lake, which had formerly been connected with the sea. Similar investigations were undertaken in 1912 by K. Stephensen, B.Sc, and Kaj Birket-Smith, B.Sc, in the fiords round Julianehaab, both expeditions yielding interesting zoological results. Independently of these researches both of the members of the latter expedition engaged in investigations of the groups of ruins in the Julianehaab District (M. o. G. LI and LIII).

In the summer and autumn months of 1912—15 Dr. Louis Bobé travelled in West Greenland, first with the object of providing a historical-topographical commentary to Egede's "Relationer om Grønland," then for general historical-geographical purposes (the voyages of discovery before Egede, the whaling expeditions and the Dutch, as well as the journeys (1751—53) of P. O. Walløe from Godthaab round Cape Farewell to the east coast (see page 29) and, finally, with the object of collecting the complete archivalia in the Southern inspectorate and arranging the Provincial Archives, which had been founded in Godthaab and Godhavn (1914), at the same time gathering material for the description of the districts which was to appear in the work "Grønland" (published in 1921).

In 1916, 1917 and 1918 Inspector O. Bendixen spent the summer in Greenland travelling through the Godthaab District and part of the Julianehaab District, in order to gather material for the description of districts in the above-mentioned work "Grønland."

In 1918 Birket-Smith was sent out to the Egedesminde District with the view of making ethnographical studies and collections. He left Copenhagen on June 5th and was back on October 3rd. The account of this journey opens with a summary of the discovery and history of the district, its physiography and climate, vegetation, animal life, population, followed by a minute description of its ethnography, with constant references to the other districts of the west coast. The account is richly illustrated, the illustrations partly being based upon material collected by himself and partly on the great collections of the Ethnographical Museum (M. o. G. LXVI).

For a long time attention had been directed towards the old churchyard at Herjulfsness (Ikigait). Judging by various finds made in that locality, it seemed that good results might be obtained from the excavation of the latter, and in 1921 this task was entrusted to Dr. Poul Nørlund, accompained by Johan Petersen, the former surveyor of Angmagssalik. The report of this expedition, which is to be found in M. o. G. LXVII, consists of three treatises.

The first treatise, which is written by Dr. Nørlund, begins with an introduction on our knowledge of the navigation of Herjulfsness by the old Norse settlers in the 13th, 14th and 15th centuries; then follows an account of the interesting grave-finds in the Ikigait churchyard, consisting of coffins, skeletons, parts of skeletons and costumes from the period mentioned above, the preservation of which seems to point towards a change of climate, and, finally, athorough investigation of the latter and the causes of the extinction of the Norsemen.

The second treatise contains an interpretation of the runic inscriptions on the coffins and wooden crosses found in the course of this excavation; this part of the work was undertaken by Professor Finnur Jonsson.

The third treatise, by Professor F. C. C. Hansen, consists of a minute account of the investigations carried on by means of the skeletons and parts of skeletons found. The results arrived at correspond with those of Dr. Nørlund, showing that the extinction of the Norsemen was due to insufficient nourishment, with the resulting infirmities and diseases.

These three reports, written by experts, on the find, which in itself is a very interesting one, make the sixty-seventh volume one of the most interesting of "Meddelelser om Grønland."

On June 3rd, in the same year, Lieutenant-Colonel P. Jensen, accompained by J. Jørgensen, of the telegraphic service, left for Greenland. The tasks to be fulfilled by this expedition were the following:

1) By means of points selected at each of the settlements to determine the longitudes and latitudes of Godhavn, Godthaab and Julianehaab, with the degree of accuracy compatible with conditions and the limited time at their disposal.
2) On behalf of the Danish Geodetic Survey, in the neighbourhood of the Godthaab settlement to reconnoitre and provisionally to establish a Geodetic Station for the astronomical longitude, to be used in future investigations of the motion of Greenland, with reference to the hypothesises of Wegener.

As the expedition carried an apparatus for the reception of wireless signals, the Danish State Telegraph Service had asked for information as to how, in the course of the journey, telegraphic and telephonic messages were heard from Lyngby Station (for which purpose "Hans Egede" had been supplied with an aerial), as well as to the qualifications of the various settlements as regards the establishment of a wireless transmitting station.

For the astronomical observations the expedition was supplied with excellent wireless instruments, as with a view to future geodetic surveys it was of importance to secure full information regarding the reception of wireless signals.

"Hans Egede" arrived in Godthaab on June 27th, and after a short stay in that place the expedition went on to Godhavn, where in the course of seven days of fine and clear weather it succeeded in determining the astronomic longitude and latitude of a certain point. From there it left for Egedesminde, where it was subsequently taken on board by "Hans Egede," on her way back from the north, arriving at Godthaab on July 12th.

On July 14th the expedition went into Godthaab Fiord to the outpost Qôrnoq, and here undertook the necessary preliminary surveys for the situation of the future geodetic station. On June 28th this work was finished, and the expedition returned to Godthaab where the longitude and latitude of a certain point was astronomically determined; then it left for Julianehaab, where a similar point was determined, and from here it once more went to Godthaab and then back to Copenhagen.

The astronomical observations which had been carried out at Godthaab on earlier occasions were of small importance as compared with the surveys of this expedition in relation to the problem of the motion of the country, but at any rate they do not contradict Wegener's theory.

As regards the wireless observations the Nauen time signals were used for the checking of the chronometers; also the Lyon, Lafayette and Annapolis time signals were heard, but those of Nauen coincided with the hours which were generally most convenient (o^h and 12^h G. m. t.).

A report of the wireless signals was handed in to the State Telegraphic Service.

Besides the above-mentioned treatises and accounts of journeys there are in the "Meddelelser om Grønland" treatises written by scientists and naturalists on studies and investigations of the material brought home by the expeditions sent out. Of such works are to be mentioned:

Joh. Lange Conspectus Florae Groenlandicae (III); O. B. Bøggild: Mineralogiae Groenlandicae (XXXII); D. Heer: Flora fossilis Groenlandica (V); treatises by several authors on the structure and Biology of Arctic Flowering Plants (XXXVI and XXXVII); A. Björnbo: Cartographia Groenlandica; Conspectus Fauna Groenlandica (XXI—XXIII), etc. For further particulars see: T. Kornerup: "Oversigt over Meddelelserne om Grønland" from 1876—1912, published by the Greenland Commission in 1913.

The "Meddelelser om Grønland" further contain the reports sent in from the Biological Station on Disko Island.

When looking back on its activity since 1877 the Commission is entitled to do so with a good deal of satisfaction. There is much in Greenland which

is left to subsequent researches, but in spite of that the Commission has been the means of elucidating so many points of interest that the knowledge of Greenland is now greater than that of any other arctic country, or even of regions in considerably lower latitudes. The "Meddelelser om Grønland" which now number 69 volumes, was already in 1885 given the "Prix de la Roquette," the golden medal of Societé de Geographie a Paris," and the work is frequently mentioned with appreciation in foreign scientific periodicals.

The achievement of these results is chiefly due to the energy, ability and devotion shown by the officers and men of science who have been entrusted with the various tasks, and to the friendly helpfulness shown by the Royal Greenland Trading Company (now the Greenland Section of the Home Office), without whose assistance the means at the disposal of the Commission would not have been sufficient to achieve the results obtained.

A special debt of gratitude is due to the Greenland officials for the assistance rendered and for the reception given to the various expeditions which have been sent out by the Commission.

Special thanks must be tended to the Carlsberg-Fund, which by its munificence and liberality has enabled the Commission to carry out many of its greatest enterprises.

Last but not least, special thanks must be tended to the Danish Parliament for the never failing understanding and interest shown towards the enterprises and activity of the commission.

ADDITIONAL NOTE

Since the above was written the following expeditions have been sent out under the auspices of the Greenland Commission:

In 1924 W. Thalbitzer spent some time in West Greenland to continue his studies on the Greenlandic language.

Since 1924 a staff of scientists have been engaged in research work round the newly established settlement at Scoresby Sound.

In 1926—27 Lauge Koch undertook an expedition from Scoresby Sound to Danmark Harbour, carrying on geological investigations and survey work.

In 1926 P. Nörlund spent some months in South Greenland, to continne his investigations of the old Norse ruins.

In 1925 and 1926 Scoresby Sound was visited by J. Charcot with a staff of French scientists, and in 1926 the Cambridge Expedition to East Greenland, under the leadership of J. M. Woordie, carried on investigations in Scoresby Sound and King Oscar's Archipelago.

In 1927 meteorological investigations were commenced in West Greenland by W. Hobbs, and at Angmagssalik by C. Dumbrava.

LITERATURE

Besides the reports from the expeditions mentioned in the article, the following works should be consulted

A. W. Greely: Handbook of Polar Discoveries. (Boston 1910).

J. Kornerup: Oversigt over Meddelelser om Grönland 1876—1926. (Köbenhavn 1926).

THE CARTOGRAPHY OF GREENLAND

BY

Commander F. H. TRAP, R.N.

Like the history of the discovery of Greenland, the description of its cartography will be divided into three periods: the older period from 982 to 1576, the period of the re-discovery from 1576 to 1721, and the period of the colonization from 1721.

I. THE OLDER PERIOD. 982—1576

For this chapter the present article is an extract from A. A. Bjørnbo's: "Cartographia Groenlandica," an exhaustive historical description of the map of Greenland within this period.

Considering the primitive medieval cartographic records, which are mainly based upon the written literature, and, further, that the compilers of maps in those days were bound by the current ideas of the world, we cannot expect to meet with an accurate description of the position and extent of Greenland.

Not until the 15th century do we meet with maps in which Greenland is represented, whereas it is mentioned far earlier in geographic records, as in a description of the northern countries, compiled about 1075 by Adam of Bremen. As far as Greenland is concerned, this description is based upon information collected in Denmark by the author. There is reason to suppose that this information was reliable, as the inhabitants of Iceland and Norway had fairly accurate ideas of the position of Greenland, but nevertheless this country is placed to the north of Norway, so as not to clash with the current idea of the world, as outlined in the so-called wheel-maps, in which the earth is represented as circular and surrounded by the infinite ocean, while the islands lying in the sea form a ring round the continent. In the 15th century Greenland is, for the first time, included in these wheel-maps, in accordance with the description of Adam of Bremen.

The geographical system which had been developed independently in Iceland and Norway during the 12th and 13th centuries included fairly

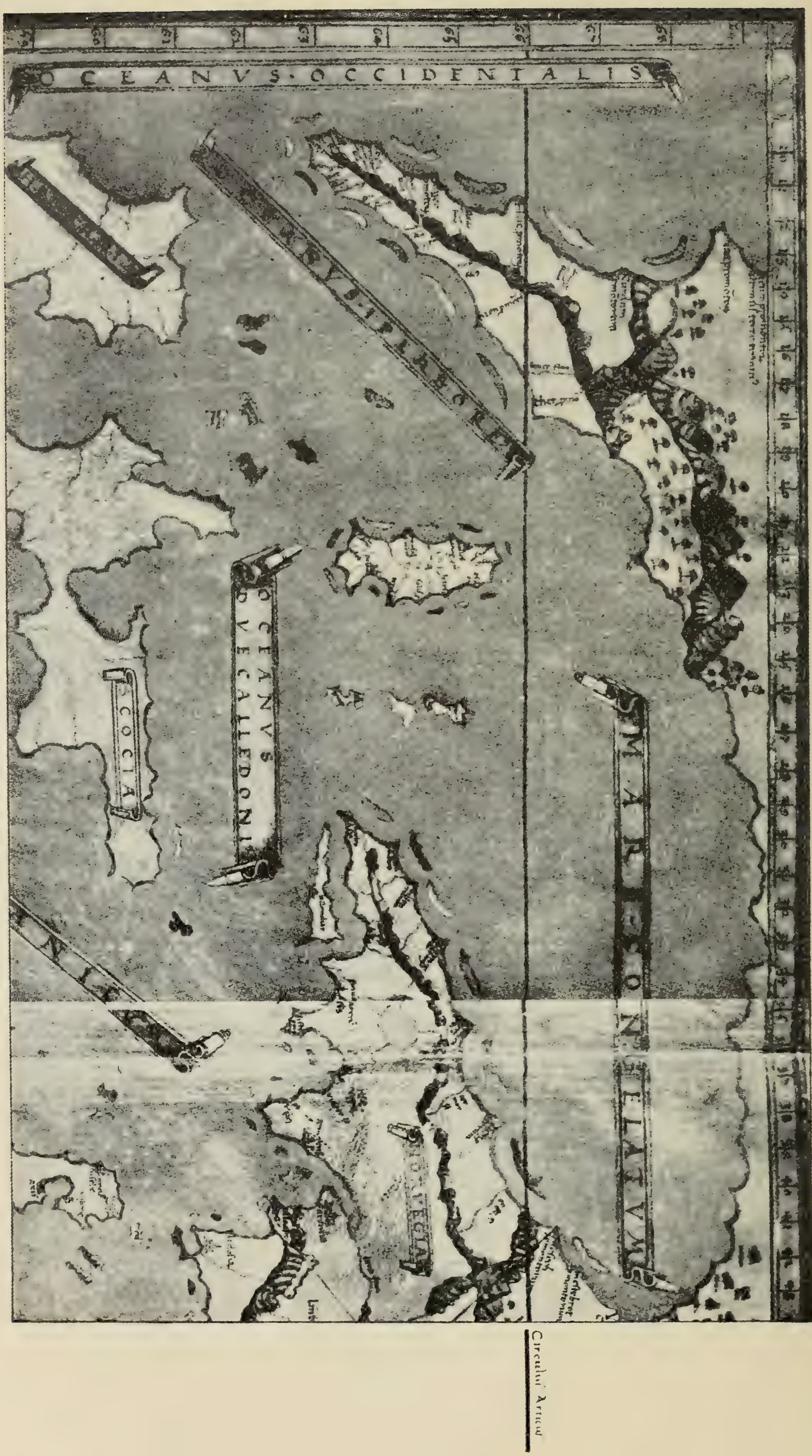

Fig. 1. Claudius Clavus' later map (A type).

accurate information on the situation of Greenland, although in order to maintain the doctrine of the continental circle it was generally supposed to be an extension of Russia.

The oldest known cartographic record of Greenland occurs in the so-called *Nancy map*, which is a copy of a map prepared in Italy (1424) by the Danish cartographer Claudius Clavus (fig. 1). The most important and reliable sources of this map which, everything considered, shows an admirable correct conception, are the sailing directions of the old Norse seafarers, through which the southern point and immediate east coast of Greenland are correctly placed in relation to Iceland and Norway. The representation of the north of Greenland is based upon reports of a country connecting Russia and Greenland and filled with fabulous people. Of the two scales of latitudes the one to the west is due to Ptolemy, the eastern one to Clavus, who probably relied on determinations of latitude—by computation of the duration of the longest day—in various episcopal cities. According to this scale the latitude of the south point of Greenland agrees very well with its actual position.

There is, further, a later work by Clavus, the so-called *A map* with the appertaining "Vienna" text. As in the Nancy map Clavus makes use of sailing directions and information derived from Norse seafarers as to navigation along the coast, possibly supplemented by his own observations. Although the more accurate eastern scale of latitude has been abandoned, the A map must be looked upon as a step in the right direction. There is the peculiarity about the Vienna text that, for the place names, Clavus used the text of an old ballad, presumably instead of numbering, and owing to the corruption of place-names throughout the years, this proceeding has put great obstacles in the way of correct interpretation. Whatever the errors of the works of Clavus, his importance to scientific geography is very great, seeing that he is the first to make a deliberate attempt to get away from the narrow medieval conception of the world, thus giving to Greenland a fairly accurate shape and position.

In the other half of the 15th century an island called "Insula viridis" and situated to the south-west of Iceland is met with in the compass charts of southern Europe. The source of this is presumably a work on the northern countries by Nicolaus of Lynn, and may in all probability be carried back to "Viridis terra" in "Historia Norwegiæ." The designation "green isle" occurs as late as the 18th century, and is maintained together with the representation of Clavus. Even in later maps one most frequently finds a "Greenland," and nearly always further to the south a "green isle."

The German cartographer Nicolaus Germanus, working in Florence, contributed to the cartography of Greenland by introducing Clavus' A-type into Ptolemy's map of the world (the *A type*) (fig. 2), but in a revision of this map (the *B type*) Germanus altered the picture of Clavus by moving

Greenland, now presumably on the strength of the name given in the ballads called "Engroneland," back to its position north of Europe, or in other words a retrograde step to the old view. The much later German cartographer, Henricus Mattellus, however retained the A type.

For completion it should be mentioned that the German cartographer Martin Behaim included the north polar countries, and so also Greenland, in his globe from 1492, for that matter the oldest globe in existence.

Fig. 2. Ptolemy's Map (the A type).

On the map compiled by the Portuguese traveller, Juan de la Cosa, representing the new discoveries in America, the "green isle" of the charts is for the first time placed in relation to the coasts of America.

Based upon the observations of the Portuguese Gaspar Corte-Real and information derived from other sources, types of maps were compiled, the so-called Corte-Real maps, which became of very great importance to the cartography of Greenland. The first of these was a map of the world, prepared in Lisboa (1502), the *Cantino type;* both as regards shape and position it shows one of the most accurate of the hitherto known representations of Greenland, which is now placed at the correct distance from the old world. The country is termed "a ponta d'Asia," which shows that the conception still prevailed of its being connected to the north with Asia. Fig. 3 represents a detail of the Cantino map, showing a correct idea of the nature of the east coast, and the map must generally be considered an improvement of the A type of Clavus. Of the Corte-Real maps at least two other types occur: the *Labrador Island* and the *Angle type.* To the former belongs an Italian map

Fig. 3. Part of a Cantino map.
The original in the Bibliotheca Estense in Modena.

of the world, the *King-Hamy map*, drawn in 1502 and presumably based upon a combination of accounts from the journey of Corte-Real, as well as a journey undertaken by English traders with Bristol as their starting point. In this type an island is indicated, "Terra laboratis," which is identical with "a ponte d'Asia" in the Cantino type, but, besides, a peninsula "Englåveland" is met with to the north of Norway. The origin of the name "laboratis"—in the form of "Labrador" subsequently used for the American Continent—is probably to be looked for in the circumstance that one of the companions of Corte-Real bore the name of "Lavorador." Whereas the Labrador-Island type hardly attained any great currency and is rather misleading, a similar importance must be attached to the Angle type as to the Cantino type. In the Angle type the south point of Greenland is correctly indicated as an acute angle, as distinguished from other representations showing an outline of the shape of a trapeze or a cup. One of these Angle maps, the *Oliveriana map*, is described as the most genuine and uncorrupted representation of Corte-Real's navigation of Greenland, and so the best illustration within the older period of the hitherto seen part of Greenland. In the cup-shaped type, also termed the *Reinel type*, Greenland is called Labrador and represented as a country open towards the north, without communication with northern Europe and only divided from Newfoundland by a narrow strait.

Although the Cantino and Angle types corroborate the correct idea of the position of Greenland, there is another view which makes itself felt in connection with it, *viz.* of Greenland as an island or peninsula to the north of Norway; add to this the idea of the "green isle" and the "Labrador Island" type, and one cannot help realizing the difficulties confronting the cosmographers of the period in question when trying to investigate cartographic material, in which Greenland had been placed in two or three different places (the *doublet* or *triplet type*).

After the Corte-Real maps a new type came into existence, the *Asia type*, in which Greenland was represented as the north-westerly extension of Asia, and where exception was taken to the placing of Greenland to the north of Norway, as well as to the communication by land between Greenland and northern Europe. However, there is still some doubt as to whether this idea is due to the Portuguese Reinel, to the Dutchman Rhuysch or to others.

The German cartographer, Waldseemüller, subjected the five different map types to a thorough investigation. Of these he condemned the Labrador type, and then, after some hesitation, he fixed upon one of the good Corte-Real types, which left a strong impress on his *carta marina* from 1516. It is true that Greenland is here called "Terra Laboratoris," but on the northern coast of the country there are traces of an effaced "Groneland."

As a proof of the difficulties to be surmounted by delineators of maps

may be mentioned the world-map of the Italian Sylvano, in heart-shaped projection, from the edition of Ptolemy, Venezia 1511. The map is a triplet map with Greenland as part of eastern Asia (Groenland), as a peninsula to the north of Norway (Engroneland) and as an island in the Atlantic (terra laboratorum).

A chart drawn by the Portuguese Pilestrina in 1511, a compass chart, is a combination of various types and appears as a doublet map, with an easterly and westerly Greenland extending towards each other in the Polar region.

Otherwise, the Cantino and the Labrador Island type soon disappeared from the charts of southern Europe, and also the Angle type played a very small part. On the other hand, the Reinel type, particularly after its introduction into the Spanish survey maps, soon became the universal one. Even as late as in the year 1600 the cup-shaped Labrador-Greenland of this type occurs, projecting far to the east of Newfoundland and taking up a great part of the north-western Atlantic. The Greenland discovered in the year 1500 was in the maps moved towards the south and mistaken for the country which now bears the name of "Labrador."

From the beginning of the 16th century there are various globes made by the German geographer Schöner and including the Polar countries. The first of these globes is a doublet map with "Viridis insula" south-west of Greenland, and "Engronell" as a peninsula to the north of Europe.

After the introduction of the Polar Continent it was also cartographically treated by others, for instance, by the French mathematician Oronce Fine on a double, heart-shaped map of the world from 1531 (fig. 4). The map must be considered an original type, being due to a combination of older types. It appears from the map that Greenland, for the first time in the history of cartography, is represented as a large island of a fairly accurate shape and position and with the name of Clavus' "Gronelant," while also the peninsula "Engroneland" to the north of Norway is retained.

Until 1532, the last year covered by the treatise of Bjørnbo, the only available direct information from ancient Scandinavia was the younger work of Clavus, the remainder of the material from which it was derived being of English or Portuguese origin. Only by the arbitrariness and combinating power of the delineators of maps, as well as by the influence exercised by the medieval conception of the world, has it been possible to produce the already mentioned manifold types on the basis of the comparatively scanty material.

The German geographer Jacob Ziegler prepared a description of the North, "Schondia," the material for which he collected in Rome. The description, which was printed in Strassbourg in 1532, first mentions Greenland and shows that Ziegler was conversant with the "Vienna" text. This description is accompanied by a map of the north, in which Greenland

connects Lapland, the Polar Continent and North America. Here for the first time an old Norse name occurs in a map of Greenland, *viz.* "Hvetsargk" on the east coast, this inclusion possibly being due to the journey of Didrik Pining.

Immediately after the publication of Ziegler's description of the north. Schöner delineated a new globe and issued a new description of the world,

Fig. 4. Part of Oronce Fines' Map.

in which he modified his former representation of the Polar regions and created a new type, the *Bridge type*, in which Greenland forms a bridge between Lapland and Newfoundland, with a pronounced contraction due west of Lapland (fig. 5).

The founder of modern geography, Gerhard Mercator, makes his first contribution to the cartography of Greenland, with a reproduction, in copper plate, of a globe representing the Polar countries. It had been prepared by his teacher, the mathematician Gemma Frisius, and the *Gemma-Frisius-Mercator globe*, as it is called, is a triplet map from 1537, on which three Greenlands are placed in a row along the margin of the Polar Continent between Russia and Newfoundland, first one "Groenbint," then a peninsula "Groeladia" and, finally, a country with five Portuguese place-names, a

kind of "Labrador-Grönland." The peninsula is placed close to Iceland and nearly north of Ireland. As regards the introduction of the Portuguese place-names there is reason to suppose that the Corte-Reale Greenland, under the name of Labrador, has first been moved down to Newfoundland, furnished with place-names from the navigation of Labrador by the Portuguese, and then again with these names has been shifted in a northerly direction on to the Polar Continent, beside the Greenland peninsula.

The same triplet type, for that matter, occurs in a heart-shaped map of the world, delineated by Mercator in 1538, but this map did not come to

Fig. 5. Schöner's Globe from 1533.

play any great part, as Mercator a few years after the appearance of the globe and the map, on which, by the way, the north-western passage is indicated, introduced a new "northern" type which will be mentioned later on.

From 1539 dates a map of the north, *carta marina*, drawn by a Swedish clerical, Olaus Magnus; this map must rather be considered a defective combination of older types, Greenland being represented as two peninsulas of small extent, suspended from the northern edge of the map, which indicates 90° latitude, and north-east and north-west of Iceland respectively. The formerly mentioned "Hvetsargk" is placed as an island to the west of Iceland, and the map indicates a north-eastern passage. In spite of the defects of this map it comes to exercise a considerable influence; thus it was introduced on a Mercator globe from 1541, the second Mercator type. On this the presumed north-western passage is replaced by the north-eastern passage of carta marina; the Greenland peninsula is altered and taken as Labrador, while Greenland is limited to a coast stretch on the Polar Continent north of Iceland. The Cologne geographer Caspar Vopell prepared three

ring globes from 1543, a map of the world from 1545 and one from 1570, all of the triplet type.

A similar type as that of Vopell is found on the *Ulpius globe* from 1542. North-west of Iceland there is a peninsula, "Groestland," and to the west of the peninsula a smaller island "Groneland" (the little Greenland Island); this island is possibly due to Portuguese charts and must be considered a

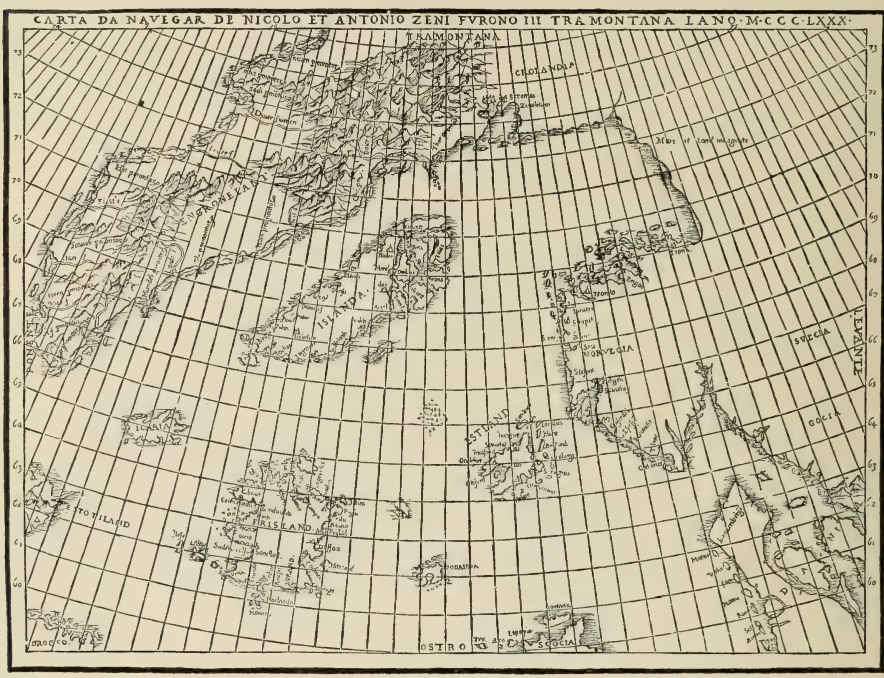

Fig. 6. Zeno's Map.

new view, which is repeated in subsequent maps; finally a "insula viride" occurs towards the south.

The charts from 1532—1550 are, on an average, corrupt imitations of the old well-known types. In the Italian maps from which they were prepared by Battista Agnese, the Greenland of the B type is drawn out in north-south, whereas on the French maps it is extended in east-west; so in a map from 1541 Desliens presents Greenland as an oblong peninsula, divided from Norway by a narrow fiord, while Desclelier's two maps from 1546 and 1550 are chiefly distinguished by ornamental details.

Owing to an uncritical treatment of the material available the Italian Gastaldi produced a rather mysterious and meaningless type, in which the united Labrador-Greenland form a semi-circle, open towards the south, round a Polar basin, frozen or filled with large islands. The type came to exercise a most unfortunate influence, in that it was adopted by later delineators of maps, among others by Berteli (1565).

In 1558 the Italian discoverer Nicolo Zeno published in Venezia a map (fig. 6), the origin of which has given rise to many different hypotheses. The Zeno map, presumably due to a Portuguese chart, represents a comparatively accurate picture of the northern countries and Greenland, which is called Engroneland, the name which has hitherto been used for the imaginary country to the north of Norway; on the other hand, there are several strange islands in the Polar Sea, among others Friesland, a corruption of "Frilanda," the name sometimes used for Iceland. The map, however, came to play a great part, as Zeno's idea of the northern country was included in the world-maps of Mercator and Ortelius, from 1567 and 1575, as well as in the map of the world, subsequently prepared by the latter, through which its influence on the picture of the northern countries, in connection with its spreading through Italian and Latin editions of Ptolemy, could be traced far into the 18th century.

A map delineated in 1570 by the Icelander Sigurd Stephanus is mainly of interest as being the first map exclusively based upon Norse sources.

II. THE PERIOD OF THE RE-DISCOVERY 1576—1721.

The sources of the present and the following chapters are the available accounts of travels, Steenstrup's photographic collection of maps, as well as the originals of the latter, in so far as it has been possible to have access to them, and, finally, the collection of maps and charts of the Hydrographic Office.

Whereas the maps mentioned in the first section chiefly deal with the presumed position of Greenland, which had not been clearly elucidated at the end of the period, and also, to some extent, with the presumed shape of the country, the various travels of discovery—those which were directly undertaken with the view of re-discovering Greenland, as well as those which only indirectly touched the country, as the expeditions sent out, for instance, with the object of finding new routes to India and China—supply the basis of new and detailed information and further contribute towards an improved indication of the position of Greenland. Generally speaking, the Zeno map must be looked upon as the original, and the imaginary island "Friesland" occurs in practically all of these maps. The "small Greenland isle" of the Ulpius type is also of frequent occurrence. A few maps, in particular world-maps, which offer no features of particular interest, will be passed over.

The travels of the first re-discoverer, Martin Frobisher, (1576—1578) leave their impress upon the two maps drawn in 1578 by the English geographer R. Hackluyt. On these map two rows of islands are indicated, situated between the south point of Greenland and the American Continent,

the most northerly being called "meta incognita" and the most easterly in the southern row "Queen Elisabeth Foreland." The water between the islands is called the Frobisher Strait (fig. 7). Frobisher, who had been led astray by the "Friesland" of the Zeno map, did not realize that it was Greenland, but presumed that it was "Friesland" he had touched at. Under various forms the "Frobisher Strait" was soon included in the Greenland maps.

In a map delineated by Michael Lock (1582) "Friesland" is placed to

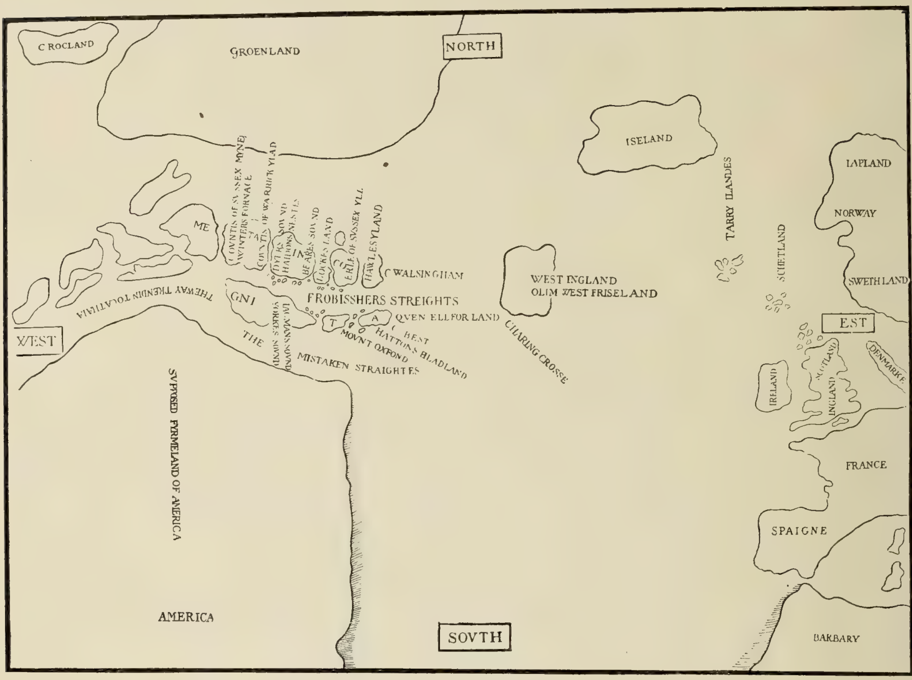

Fig. 7. Frobisher's Map

the south of Greenland, with a fairly accurate indication of the south point of the island, in so far as Friesland is included with Greenland proper.

Based upon the Zeno map the Dutch navigator William Barentz in 1598 prepared a map of Greenland, including the Frobisher Strait according to the most recent information, besides Friesland and the small Greenland Island.

The *English map of the world*, prepared in 1600 on Mercator's projection (by Shakespeare termed the "new map") illustrates the travels of Davis and is also of the Zeno type. The water between Greenland and America is, as at the present time, called the Davis Strait, whereas the *Frobisher Strait is looked upon as a water cutting off part of the south point of Greenland.* Of subsequently used place-names should be mentioned Cape Desolation, where Davis made a landing.

From the expedition sent out by Christian IV (1605) originates a manuscript with four maps, based upon the observations made and prepared by the English navigator Hall, the pilot of the expedition. The one map

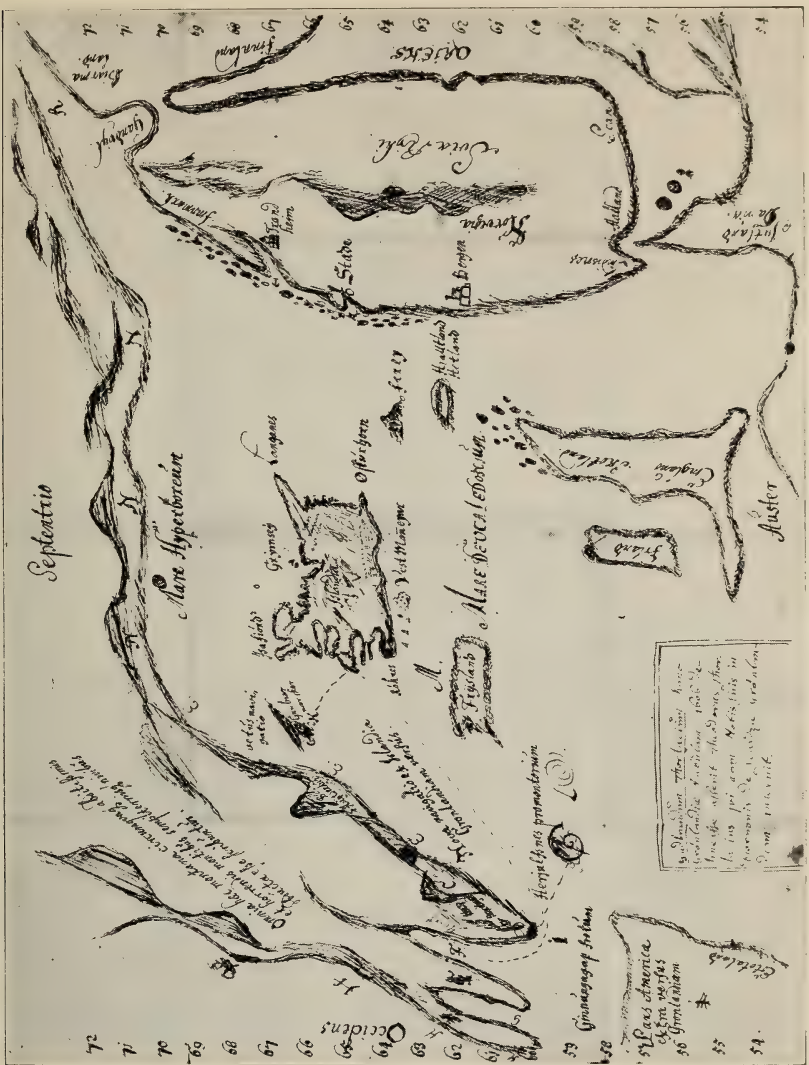

Fig. 8. Gudbrand Thorlacius' Map.

comprises the whole of the investigated distance, while the three others represent the three fiords, King Christians Fiord, Cunningham Fiord and Brede Ransson's Fiord. When critically comparing these maps with the most recent ones, one cannot help remarking the care and accuracy with which they are drawn.

As a *special type* may be mentioned a map dating from 1606 and drawn by the Icelander Gudbrand Thorlacius. The southern point of Greenland

is indented in a north-south direction by two deep fiords, and the water between Greenland and America, which is made rather narrow, is called "Ginungagap," corresponding with the Frobisher Strait of the Hakluyt map (fig. 8).

On the Mercator atlas of the Dutch delineator Hondius (1608) the representation of Davis and Frobisher Straits agrees with that of the English world map from 1600.

The travels of Hudson are illustrated on a map of the northern countries, delineated by Hondius in 1611, as well as by a map drawn in Mercator's projection by Hudson himself and published by Hessel Gerritz (1612). The two maps, which may be looked upon as an improved Zeno type, agree fairly well and are provided with a number of English place-names, as, for instance, "Desolation," and on the map of Gerritz the name "Farewell" is for the first time used about the south point of Greenland, not, however, the present Cape Farewell, but the somewhat more westerly Cape Christian. The name "Hold-with-Hope" on the map of Hondius denotes the most northerly part of the east coast sighted by Hudson. Whereas Hondius includes the Frobisher Strait, it is on Hudson's map only indicated by a deep, nameless incision into the east coast.

In close agreement with Hudson's map is the map, drawn in 1612 by the English navigator, Gatonbe, who derives his information from the last journey of Hall, in which he took part. Besides Friesland to the south-west of Greenland, the map further indicates a large island between Iceland and Greenland, and close to the north and south of the latter the inscription "Frobisher Fishing" and "Bank of Fishing," respectively. The island and the fishing bank may presumably be considered the cause of the inclusion, in the later Dutch maps, of names derived from Icelandic writings, *viz.* "Gudbjörnöerne" and "Gunbjørnskærene." In the map (fig. 9) one notes the re-introduction of Frobisher Strait, as well as numerous English place-names, of which "Harbour of Hope," "Cockenford" and "Romblaford" correspond with the present Godthaab, Sukkertoppen and Holsteinsborg. The map may be looked upon as the foundation of the later Dutch type (Carolus, 1634).

In a map of the Hudson Bay, which accompanies P. Lauritzen's edition (1883) of Munk's "Navigator Septentrionalis," 1627, a few of Munk's names are given in parenthesis. So the strait between Greenland and America is called "Christians-Strædet," Frobisher Strait is called "Isfjordene" and the south point of Greenland "Munkenæs."

Based upon his own observations the Dutch navigator Joris Carolus, in 1634, drew a map which may be looked upon as the type of subsequent maps, particularly of Dutch origin. The map greatly resembles that of Gatonbe, but introduces a new strait to the north of the Frobisher Strait, besides altering the outline of the east coast, which in about lat. 65° N. is

given an east-west direction and is strongly indented, presumably as an attempt to illustrate the old accounts from Ivar Baardson (about 1400); further, the name "Cape Farewell" is replaced by "Staatenhoeck."

Baffin's travels caused the appearance of the map of the English captain Luke Fox (1635), which south of lat. 75° N. provides a fairly accurate picture of Greenland, and is particularly remarkable by placing Frobisher Strait as a water between some islands on the east coast.

In Henry Hexham's edition (1636) of the atlas of Hondius there is also

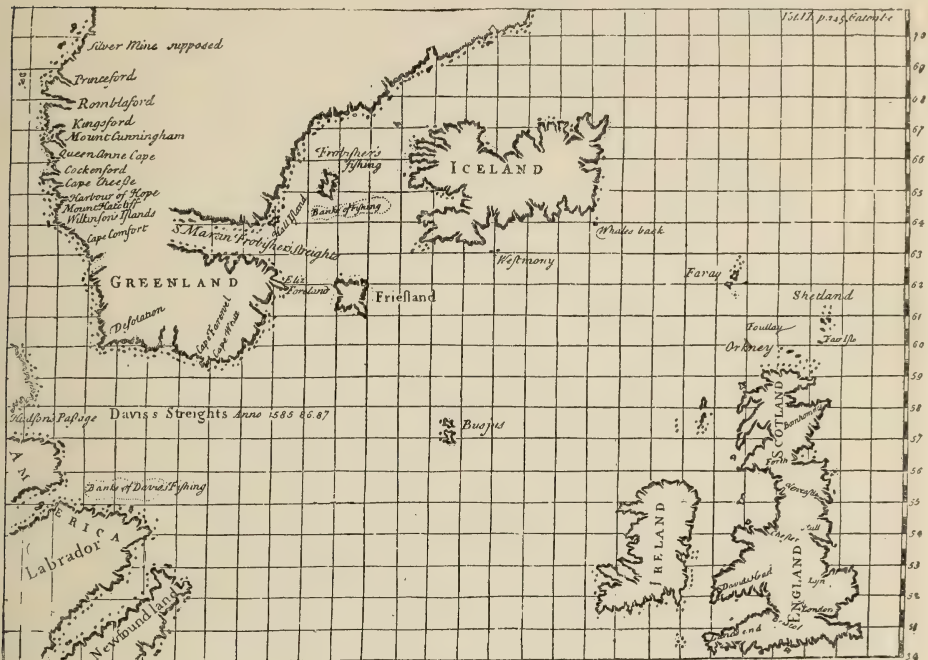

Fig. 9. Gatonbe's Map.

a map illustrating the observations of Baffin. Of place names particular note should be taken of "Smith's Bay," the origin of the "Smith's Sound" of more recent maps.

From 1640 dates a map, drawn by the Icelander John Gudmundson and strongly influenced by the Icelandic type of Gudmund Thorlacius, though he has a somewhat different conception of southern Greenland, which is inscribed with the names "Øster Bygd" and "Wester Bygd", and so comes to play a part in the investigations of the position of these settlements.

From Italian sources originates a map from 1647, drawn by Arcano dell Mare. This map deviates from the Dutch as well as from the Icelandic type, though for the southern part it is possible to trace some resemblance to the map of Gudmundson.

The maps of the French historian, Peyrère, (1647), influenced by the maps of Hackluyt and Gudmund Thorlacius, prove through the peculiar view expressed, that delineators of maps, in spite of the existing fairly good representations, were still rather uncertain in their conception of Greenland.

To the Carolus type belongs a map, prepared in 1652 by the Dutch navigator and delineator of maps, Johannes Jansson, which map is only distinguished from that of Carolus by the smaller extent of the indented part of the east coast.

From the Danish expeditions under Danell originate a number of strange maps, drawn in 1653 by the Dane Johannes Mejer. They are based upon Mercator's conception of Greenland, but the country is split up into a number of well-populated and well-covered islands, and names from old accounts and Eskimo names (taken from the German discoverer Olearius) are scattered about in rather an indiscriminate manner.

In 1656 Jansson further contributes a map which deviates somewhat from that of 1652, but which as regards the shape of Greenland must be considered the best representation hitherto given, (fig. 10). The two straits through the southern part have been taken away, and under the influence of Luke Fox's map the Frobisher Strait is placed as a fiord on the east coast. On the other hand, Friesland is retained. The maps of Jacob Aertz Colom from 1660 must rather be looked upon as a combination of Jansson's map from 1656 and the map of Carolus, seeing that the outline resembles that of Carolus, while the two southern straits have been left out.

The map accompanying the report given by Chr. A. Lund (1664) of Danell's voyages is a copy of Gudmund Thorlacius' map from 1606, in which the routes of Danell are laid down. The most easterly fiord in the southern part is called "Ericksfiord," and of formerly mentioned place-names "Hvitserk" is noted.

The map of the Dutch publisher of maps, Hendrick Dancker (1666) is an imitation of Jansson's modified Carolus type from 1652, and was used by the Icelander Thordur Thorlacius in his map from 1668, in which, however, the most northerly of the two straits through the southern part is called Frobisher Strait, and on which the east coast only deflects towards the east in about lat. 69° N., instead of in lat. 65° N. as on the map of Carolus. The islands at the south point of Greenland have been taken from Peyrère. The map is inscribed with "Øster-" and "Vesterbygd," as well as on the east coast with numerous place-names of Icelandic origin, and it may be considered a *Dutch-Icelandic type* (fig. 11). It has been copied in Torfæus' "Groenlandia Antiqua," but owing to an inaccuracy on the part of the delineator the inscription of "Vesterbygden" and Østerbygden" extends as far as lat. 70° and 67° N., which inaccuracy came to exercise its influence on subsequent maps.

From Baffin's voyages dates a map of Baffin's Bay in Molls Atlas, 1706.

Fig. 10. Johannes Jansson's Map.

This map contains a number of place-names which agree with Hexam, 1636, and Jansson, 1657. It is further to be noted that Munk's name for Baffin Bay, *viz.* "Mare Christiania," is introduced, and also the possibility of a passage north of Greenland is indicated by the alteration of Hexam's "Smith's Bay" to "Smith's Sound."

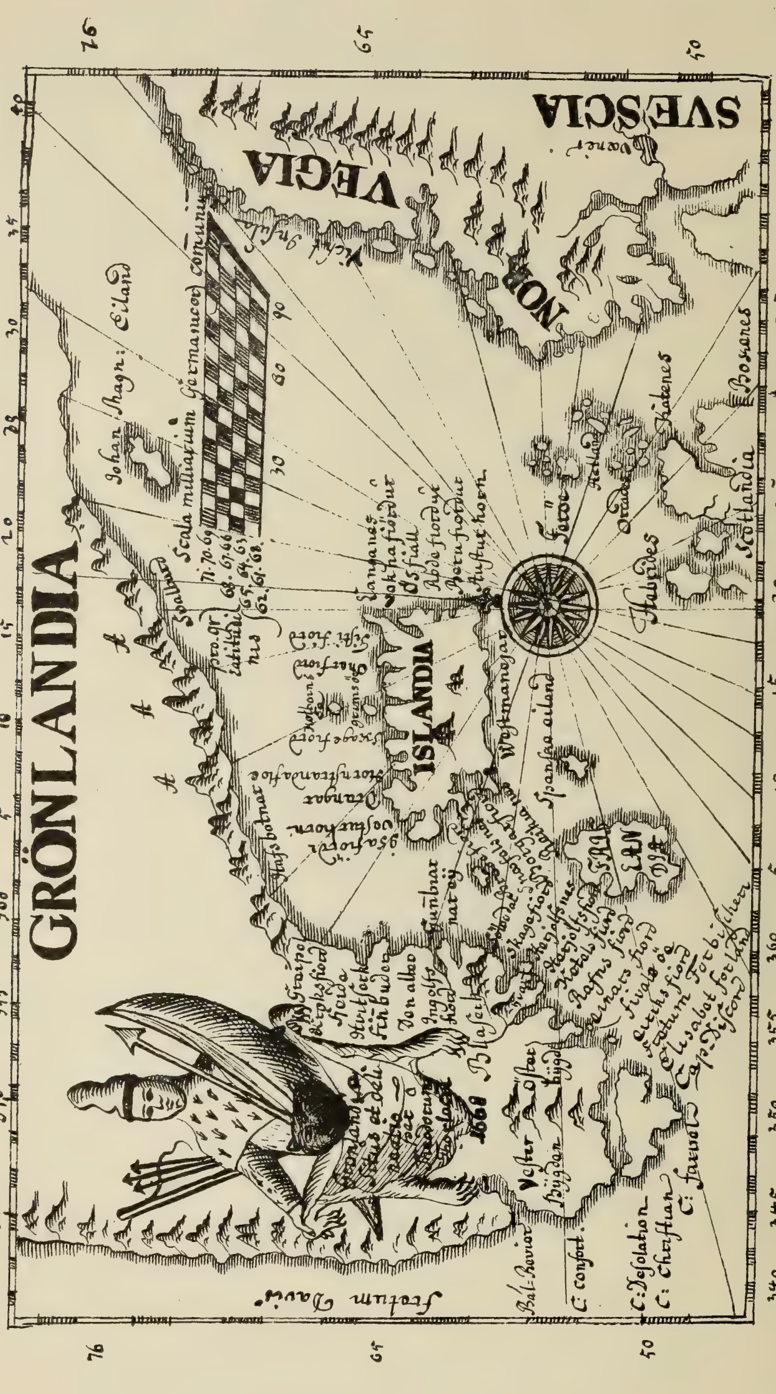

Fig. 11. Thordur Thorlacius's Map.

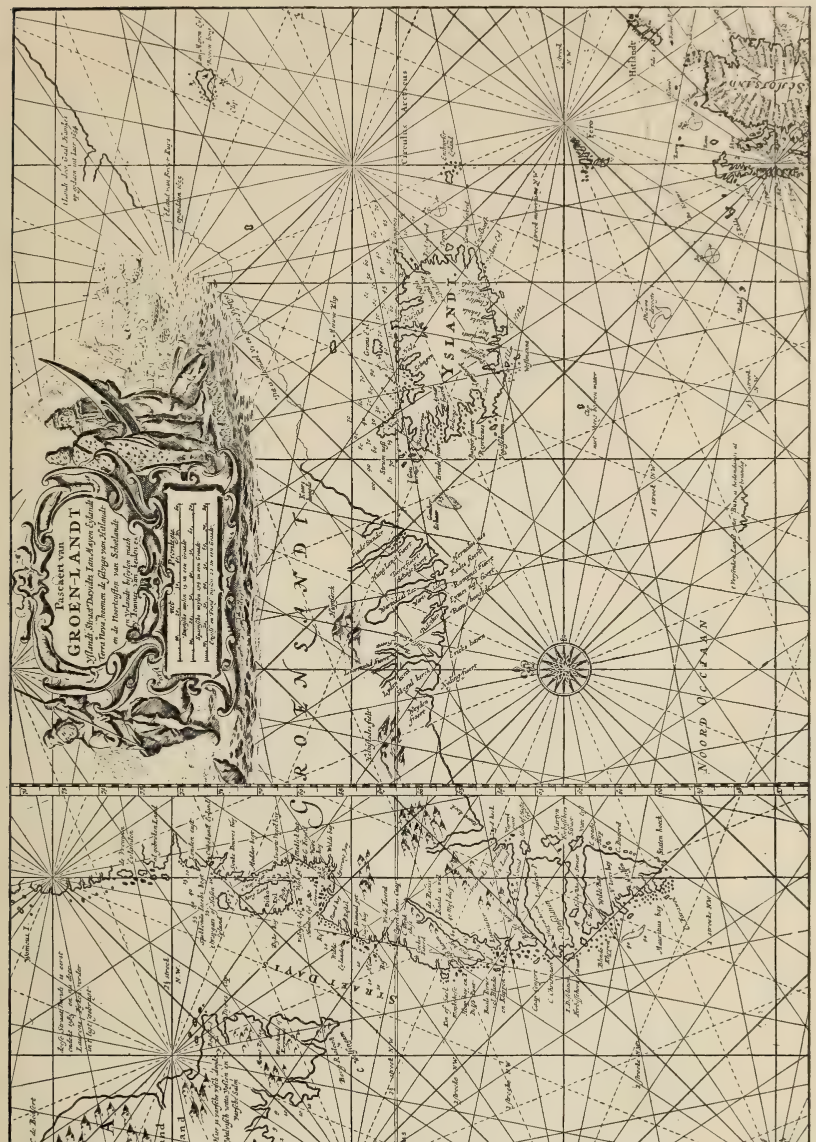

Fig. 12. Van Keulen's Map.

Between 1681 and 1687 the Dutch publisher of charts, Johannes van Keulen, issued a large atlas, "De nieuve groote ligtende Zeefakkel," based upon available sources and supplied with more recent observations made by Dutch navigators. In the edition of Gerhard van Keulen (1709) there is a map of Greenland which is an imitation of the maps of Jansson and Dancker (from 1652 and 1656, respectively) with a few improvements. The map was published separately in 1720, with additional information supplied by Feykes Haan and with a special map of Disko Island with "Vaigat," introduced into the map of Greenland by van Keulen. The map (fig. 12) is very detailed and contains many place-names of earlier as well as of more recent origin. The northern strait through the southern part is called "Bear Sound," and of names transferred to the maps of the present day should be noted "Wester Eyland," "Zuid Bay" and "Jacob's Bay." Of particular interest is the shape of "Ball's Revier" as a long narrow fiord in a N. N.W. direction, and the inclusion of a "Staaten Hoeck," corresponding with the present Cape Farewell, as well as a Cape Farewell somewhat to the west of the latter. Friesland has disappeared, and in the presumable position of this island the map bears the inscription "versonken land van Bus." On an undated map by van Keulen the east coast from lat. 70° to 80° N. is laid down under the name of Ny-Grønland, with various place-names originating from Dutch whalers. Of these names "Lambert's Land," "Gael Hamke's Land" and "Edam's Land" have been transferred to later maps. To the Dutch publisher of charts, Zorgdrager, are due two maps from 1720, *viz.* a map of Greenland, which is mainly copied from van Keulen's map, as well as a map of the Polar countries, which still shows Greenland as a peninsula pendent to the Polar Continent.

The maps of van Keulen and Zorgdrager mark the close of the period of the re-discovery and may be considered as the current type of the picture of Greenland in those days. The outline of the west coast agrees fairly well with actual conditions, whereas this is not the case as far as the east coast is concerned, although Jansson's map from 1656 comes closer to reality. Whereas the observations along the west coast were taken during landing or at close quarters, the opposite was the case on the east coast, the latter being made under conditions which differed greatly as regards the width of the ice belt and visibility, and so the outline given must rather be looked upon as the result of a somewhat free fancy in the endeavour to combine older and newer records.

As regards the position of Greenland, the latitude of the south point is correct, its longitude about 3° too far east.

III. THE PERIOD OF COLONIZATION

1. (1721—1800.)

During the colonization period numerous special maps came into existence, representing the settlements according as they were founded and their immediate surroundings. The expeditions starting from the settlements —several of which with the object of identifying the old Østerbygd—contribute towards the cartography of the coast between the settlements and profit by the intercourse with the Eskimos, whose inborn local sense and intimate acquaintance with actual conditions are extremely valuable. Alongside of this development maps are published, illustrating the observations made on older as well as more recent Arctic expeditions. As it would carry us too far to mention all of these maps, a few which do not contribute any independent information will be omitted.

The work of the first Dano-Norwegian settler, Hans Egede, has been dealt with elsewhere. His first contribution to the carthography of Greenland were a special map of Ball's Revier (the Godthaab Fiord), prepared in 1722, and a coastal map from 1724, comprising the west coast from 3° south to 2° north of the fiord.

A map drawn by Bussæus, in 1726, is essentially an imitation of that of Thorlacius. Although this map is said to be prepared on the basis of old and new accounts, with the best maps as its model, Frobisher Strait is included, and this in spite of the fact that the attempt at traversing the strait which was made in 1723 by Hans Egede yielded the result that the strait did not exist. The name "Eriksfiord" is taken from the Icelandic type, but is transferred to the east coast as the designation of the most westerly of the fiords which extend in a northerly direction. When the map was reissued in 1733, van Keulen's view of the southern straits was adopted.

From 1728 there are three unsigned charts, *viz.* two of the water at Nepisene and one of Ball's Revier, the latter, further, being the subject of a map, drawn in 1731 by Lieut. A. Gerner of the Danish Navy. Based upon reconnoitring trips along the west coast of Greenland the Dane Matthias Jochumsen outlined the coast between lat. 60° and 67° N.

In 1740 Hans Egede, besides preparing an improved map of "Ball's Revier," made his greatest contribution towards the cartography of Greenland by constructing a map of the whole of Greenland south of lat. 71° N. Even though the picture of Greenland is not as yet quite complete, his above-mentioned unsuccessful attempt at traversing the *Frobisher Strait had established its non-existence* and so given rise to a special type of map which, with full justice, may be called the Hans Egede or the *Danish type* (fig. 13). The south point is represented as a comparatively small island, to which Cape Farewell is referred, whereas Statenhoeck is placed on the

continent. The inscription across the map shows the view of an older period as regards the connection with the eastern settlement. Hans Egede's essentially correct view of South Greenland was in 1746 introduced into a map

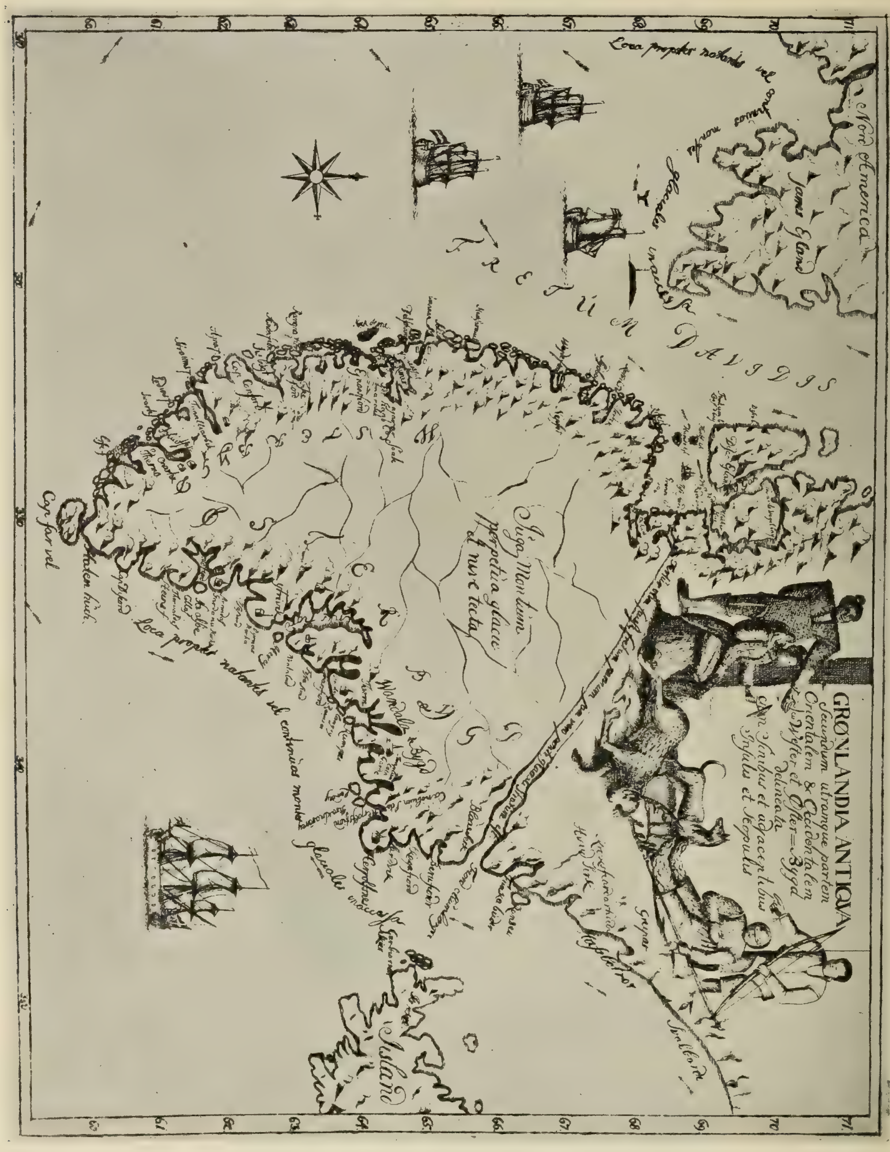

Fig. 13. Hans Egede's Map.

drawn by the Hamburg senator Anderson, which map has otherwise many points of resemblance with that of Zorgdrager. Nevertheless, the erroneous view represented by the Dutch maps is continued, though in a slightly modified form, on a map in Brouchner's Atlas, the Hague, 1759.

David Cranz' "Historie von Grönland," 1765, is supplemented with a

map of Greenland south of lat. 73° N. as well as a special map of the west coast from Isblink as far as lat. 73° N. The former is in its main features of the Hans Egede type and has, as a further source, the diary of Peter Olsen Wallöe, while the east coast is influenced by Th. Thorlacius. Of place-names should be noted the names of the previously founded settlements as well as "Isblink," a glacier which already in Dutch descriptions was mentioned as "Witteblink." By referring the name of "Frobisher Strait" to the fiord "Sermeliarsok" on the south-western coast, an explanation is given of the former erroneous conception of this water, the presumable position of which is marked in stippled lines. Also Bär Sound is included as a fiord on the south-west coast. From the same sources as those used by Cranz Poul Egede, who as early as 1738 compiled three fairly uniform maps of Disko Bay, has drawn his material for a map of Greenland south of lat. 73° N. This map dates from 1773, and the names of the later settlements were included, the inscription of Hans Egede being retained. Among the names of the east coast, which for the greater part were taken from Torfæus, a new name "Wandala-Bygd" is to be noted.

From 1774—1775 there are four maps of the districts *Godthaab, Sukkertoppen, Holsteinsborg and Fiskernæsset*, the two former being drawn by Thorhallesen, a missionary, and the two latter by Raun, an employee of the Greenland Trading Company. With the exception of the names of the settlements as well as the name "Hellefiskebanke" off Sukkertoppen, which here occurs for the first time, the place-names are of Eskimo origin. The *Julianehaab* District was mapped in 1779 by Arctander and *Frederikshaab* in 1780 by Andreas Bruun, both holding appointments at the settlements. A map south of lat. 67° N., dated Havnia 1780, was drawn at the initiative of Sæmund Holm. As far as the west coast is concerned, the source indicated is the reconnoitrings of Hans Egede in 1723 and 1724. The names and shape of the east coast show the influence of Torfæus.

In 1783 O. Olavsen contributes an excellent map of the west coast as far as lat. 77° N., as well as a map of the coast north of Upernivik. On the first of these maps the sources used are indicated, *viz.* Egede, Cranz, Anderson, Bruun, Raun and Thorhallesen. The boundaries of the districts are, according to information given by Hans Egede and Thorhallesen, included as straight lines. The position of Cape Farewell is taken from the determination of a French observator. The second map is drawn from the accounts of an Icelandic skipper, Gudmundson, who navigated the coast in question, which is charted as a row of islands, with a note to the effect that the outline of the country is unknown, as the water inside the islands is filled with ice.

The map supplementing Forster's "Geschichte der Entdeckungen in Norden," 1734, and comprising the Arctic region, yields a complete picture of Greenland, based upon the most recent sources and showing the still presumed connection with America.

In 1788 Poul Egede drew another map (fig. 14) which is an improved edition of the older one. The title indicates that "the west side is charted

Fig. 14. Poul Egede's Map.

and improved in comparison with subsequent information, and the east side according to Torfæus." When a promontory on the east coast is called "Cape Frobisher," this must be entirely due to a feeling of veneration to-

wards the famous navigator. The position of Godthaab is laid down according to the astronomical observations of the Danish missionary Ginge.

Lieut. C. Th. Egede, Danish Navy, who was a member of Løvenørn's Expedition, made a sketch of the east coast between lat. 64° 15′ N. and lat. 66° 20′ N., based upon observations taken outside the ice margin.

To Eggers' prize essay of 1791 belongs a very interesting map, which shows that he thought the "Østerbygd" was situated on the south-western coast near Julianehaab. The map of Arctander was used, but the Icelandic names, by Torfæus referred to the east coast, are here transferred to the south-west coast, such as Eriksfiord, Hvalseyrafiord and others.

When summing up the cartographic picture of Greenland as represented at the end of the 18th century, it is with full acknowledgment of the great results achieved through the energetic efforts of the Danish settlers. A detailed comparison of the *Hans Egede type, as improved by Poul Egede* would carry us too far, and so it should only be noted *that* the west coast north of Sukkertoppen is too easterly—thus the longitude of the western side of Disko Island is about 49° west of Greenwich instead of 55°—*that* the intersection of 66° latitude with the east coast is indicated at 29°, instead of 35° W., and, finally, *that* the position of Cape Farewell is very nearly correct.

2. (*1800 to the Present Time*).

This period comprises, on the one hand, a resumption of the voyages of discovery to uncharted regions, on the other, expeditions with the object of carrying out systematic surveys. As the knowledge of the original maps quickly spread to the geographical societies and cartographic institutions of the various countries, thus causing the appearance of numerous copies, the reservation made in an earlier chapter as to the leaving out of less important maps also applies, and in a still higher degree, to the present chapter.

An important alteration in the Greenland map was introduced through Ross' map of Baffin Bay, originating from the voyage of 1818. The coast line north of Coquin Sound (Sukkertoppen) is carried farther west, marking an improvement of the longitude in the Egede type, the coast line of which is also shown in the map (fig. 15). Of additional place-names which have been retained, mention should be made of Melville Bay and Cape York.

In a map from 1814 of Disko Island the German mineralogist Giesecke rather modifies the shape of this island, which is incised by deep fiords from the west.

Whereas the Dutch-Icelandic view of the east coast held good during the period of colonization, W. Scoresby in 1822 carries the mapping of the whole of the outer coast—from about lat. $69^1/_2$° to 75° N. — a great step forward. The mouth of the deep fiord in about 70° 21′, bearing the name of Scoresby

Sound, was, however, navigated and charted by the Danish whaler Volquard Bohn as early as in 1761.

Based upon the newest information Scoresby, further, drew a map of the *whole of Greenland.* The west coast north of Sukkertoppen is taken from

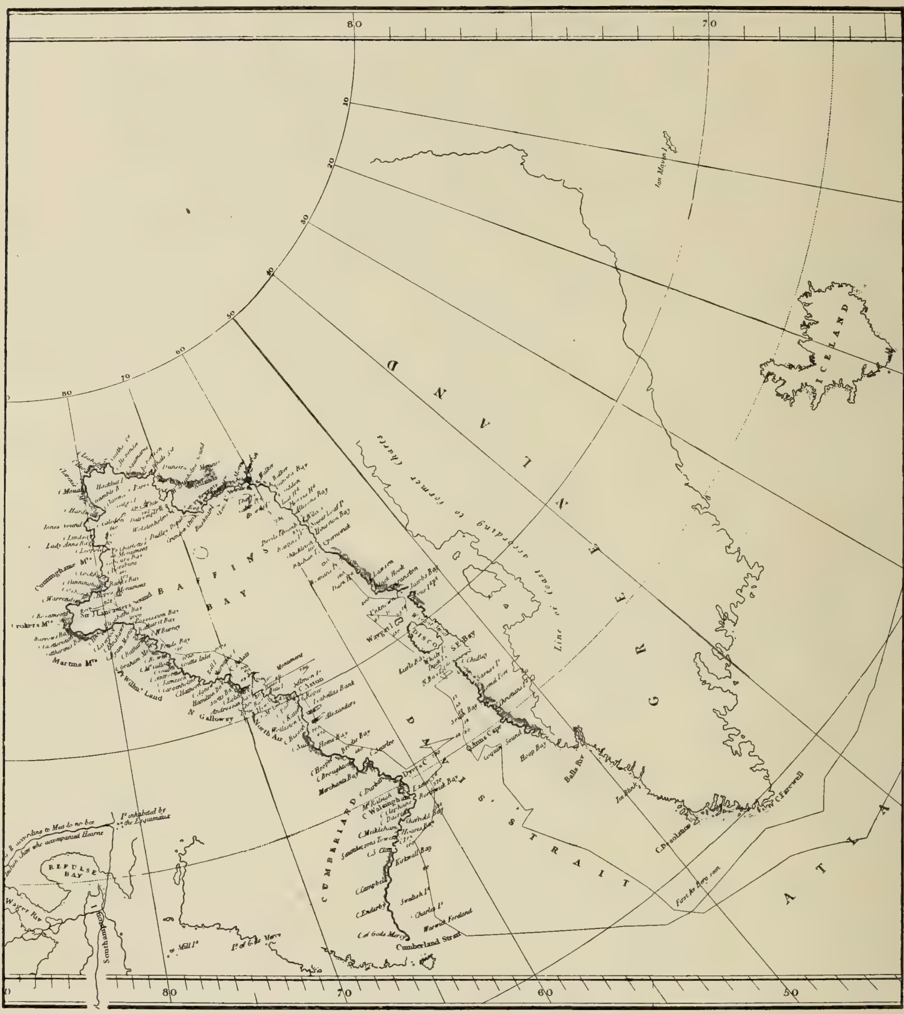

Fig. 15. Ross' Map.

Ross, Disko Island from Giesecke. On the northern part of the east coast the coast line, as formerly presumed, is shown, and farther south it still bears the Icelandic names.

From Parry's voyage in 1824 date some charts of harbours and anchorages on the west coast, published by the Hydrographic Office, London, 1825. As a supplement to Giesecke's treatise on the position of the Østerbygd should be mentioned a detailed map of South Greenland, without however, any place-names.

Upon the initiative of the Government Lieut. Graah, of the Danish Royal Navy, contributed largely to the knowledge of Greenland by undertaking *astronomical* surveys for a number of the chief points between lat. 68° 30′ and 73° N. (the northern inspectorate). The longitude of Godhavn is directly determined, with that of other points in relation to it. The longitude in modern maps is, as far as the western settlements are concerned, mainly taken from the determination of Graah.

In a work issued, in 1825, by the Danish Hydrographic Office Graah gives a description of the coast stretch surveyed, supplemented by a map (on Mercator's projection) of the west coast of Greenland from lat. 68° 30′ to 73° N., as well as 8 charts of the most important anchorages of the district.

The geographical atlas of van der Mahlens, Brussels, 1827, includes five sectional maps of Greenland, comprising the west coast to about lat. 77° N. and the east coast to about lat. 76° N. The maps are based on the most recent information obtained; among other sources given is the voyage of Clavering (1823) to the east coast between lat. 72° and 76° N.

Of new place-names are to be mentioned Shannon Island, Clavering Island and Pendulum Island, where Sabine made his pendulum observations. In 1828 the Geographical Institute of Weimar published a map of Greenland and adjoining countries, prepared in Copenhagen by Th. Gliemann. This map is also based on the newest material available and bears the inscription "Egede's Land" on the east coast, in about lat. $66^1/_4$° N.

Of the greatest importance to the cartography of southern Greenland are the well-known voyages of Graah, undertaken in 1828—1829 along the coast from Frederikshaab, south of Cape Farewell, and along the east coast as far as lat. 65° 14′ N. The map prepared on the strength of observations made during this voyage and astronomical observations, was issued at Paris, in 1829, and yields a *completely altered picture of the east coast.* The material collected in the course of Graah's voyages caused the Danish Hydrographic Office to publish, in 1832, its first map of Greenland where, besides the numerous sketches of Graah, the following sources are given: Scoresby, Giesecke, Ross, Parry, Egede, Dannell, Hall, Pickers, Gill, Ginge and van Keulen (fig. 16). The fact that the names "Cape Farewell" and "Staatenhuk" are given to the same promontory show the correctness of Graah's view of the identity of the English Cape Farewell and the Dutch Staatenhuk. Apart from the east coast between the point where Graah turned back (Vend-om Øen) and Scoresby Sound, which distance is only indicated by a dotted line, the map, as an improvement of the "Danish type," forms an excellent standard type, the *Graah type*, for the use of later cartographers. In subsequent editions an outline of the coast south of Scoresby Sound is included, based upon the observations of Blosseville in 1833.

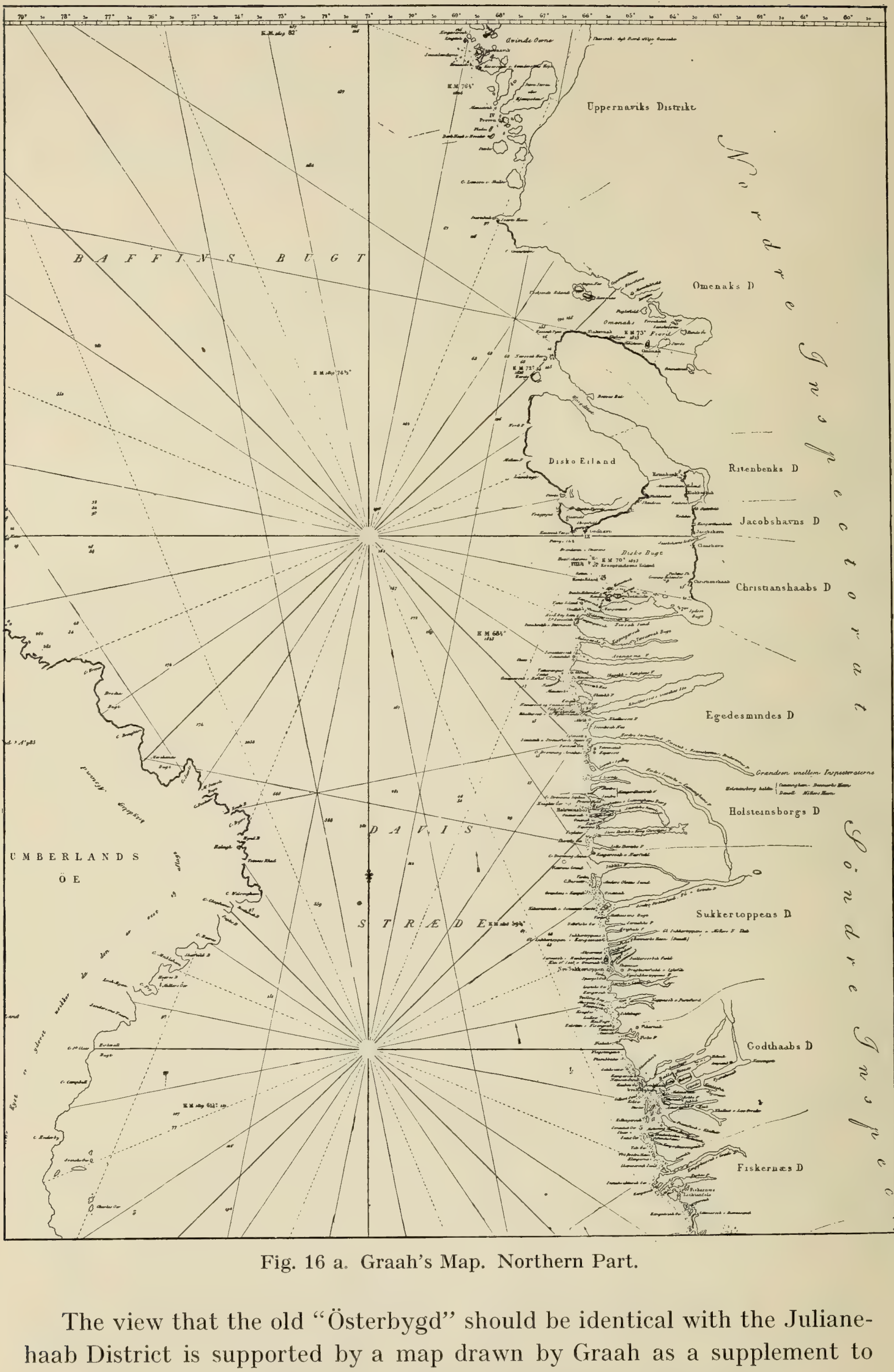

Fig. 16 a. Graah's Map. Northern Part.

The view that the old "Österbygd" should be identical with the Julianehaab District is supported by a map drawn by Graah as a supplement to C. C. Rafn's "Antiq. Americanæ." "Grønlands historiske Mindesmærker," III,

1845 has, as a supplement, two maps of the Godthaab and Julianehaab Districts, the object of which is the identification of the "Vesterbygd" and "Österbygd" respectively, the former being prepared by H. P. C. Møller

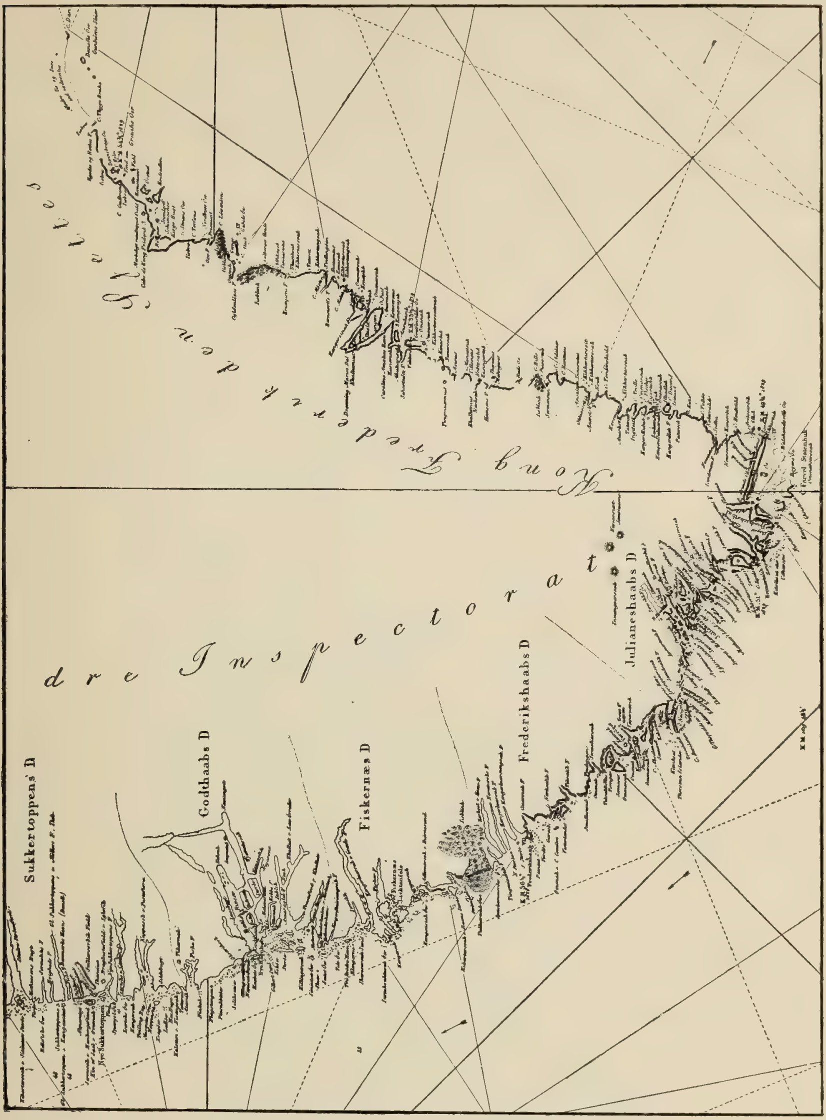

Fig. 16 b. Graah's Map. Southern Part.

1840, and the latter after Graah with later corrections and additions. With the same object Rafn in 1845 drew a map of the Österbygd from old Norse accounts.

The chart of the Hydrographic Office was introduced into a map of the Polar regions published by John Murray in London, 1847, the latter being included in Barrow's description of Arctic travels.

The hitherto prepared maps only supply information of the outlines of the country; as regards its character anyone desiring knowledge is referred to the descriptions and a few landmarks. This deficiency was remedied by the map accompanying H. Rink's description of the Danish trading district in northern Greenland, published in 1852 by the Royal Danish Scientific Society, this map being "prepared from observations made in the course of a journey undertaken in the year 1848—51 with the object of carrying on geognostic and mineralogical researches and based upon the position of the points determined by Capt. Graah by means of astronomical observations." Consequently, the map gives a good picture of the heights in the above-mentioned districts, and indicates the glaciers (ice-currents) in which the icebergs originate.

The expeditions of Inglefield and Kane, sent out with the object of searching for Franklin, were the indirect cause of a renewed and improved mapping of the northern part of Greenland. From the journey of the former dates a map, published in 1853, and terminating towards the north at lat. 78° 21′ N., the northernmost point attained by the expedition. Smith's Sound is placed as a rather broad water between Prudhoe Island in Greenland and Ellesmere Island. Kane's map from 1855 further extends our knowledge of these regions, as with Kane's Sea, the continuation of "Smith's Sound", and farther north the Kennedy Channel between Washington Land and Grinnel Land. North of the point where the expedition turned back, *viz.* lat. 80° 10′ N. "open sea" is indicated. It should, further, be noted that Inglefield surveyed Upernivik Harbour and undertook an astronomical survey of Holsteinsborg.

At the hand of Rink there is further, from 1856, an improved map of the Julianehaab District, as well as a carefully drawn map of the northern districts of South Greenland, forming a supplement to the second part of his description of Greenland, and a map of Greenland "relating to the distribution of the inland ice."

On the charts published by the Hydrographic Office (1857 and 1859) of the "northern ocean" and the "northern Atlantic", respectively, Greenland is, for the first time, included in a Danish chart.

A chart of Smith's Sound from 1861, showing the route and discoveries of Dr. Hayes in 1860—61 supplies a somewhat modified picture of the northwest coast of Greenland as far as Washington Land. The coast between Melville Bay and Kane Basin is in the main laid down in close agreement with actual facts, more particularly through the introduction of Whale Sound, the deep Inglefield Bay and the Northumberland Islands, situated off the latter; on the other hand the indicated width of Kennedy Channel is too great.

In 1863 the Hydrographic Office issued a sketch map of the southern part of Greenland, south of lat. 62° 30′ N. This map, which deviates some-

what from that of Rink, is a compendium of all the best material available, and contains various special maps with indications of depths. In 1866 was published a map of the Arsuk Fiord with special maps of various harbours, among others Ivigtut Road. The map, which is used to this day, is prepared on the strength of surveys made by Lieutenants Falbe and Bluhme of the Danish Navy, and based upon astronomical surveys. In the same year a sketch-map was issued of the west coast from Arsuk to Holsteinsborg (lat. 61°—67° N.) with special maps of the Godthaabsfiord (Ball's Revier), as well as of the harbours of Godthaab and Holsteinsborg with indications of depths. The map of the Hydrographic Office was adopted in the charts issued by the English Admiralty and Hydrographic Office.

From the same year dates a map, with Eskimo text, prepared by Kleinschmidt. For the preparation of this map he made use of sketches from his numerous voyages, as well as of the best sources available, among others a few special maps printed in Godthaab, some of which are based upon sketches, *excellently executed by Eskimos*. The map was subsequently used as a supplement to Rink's "Danish Greenland," London 1877.

In Nordenskjöld's description of his expedition to Greenland in 1870 there is an edition of a map of Disko Island with its surroundings, drawn by Rink at an earlier period and modified in accordance with determinations of positions and surveys made in the course of this expedition.

The Germania-Expedition, 1869—1870, extended the knowledge of the east coast; the distance from Pendulum Island to Cape Bismarck—about 90 miles—was mapped, and the distance from the same island southward to Franz Joseph' Fiord was again subjected to investigations. The results obtained are illustrated by the maps supplementing the description issued in Leipzig 1874, *viz.* one map of the "Routes and Discoveries of the Expedition," drawn by W. Reinert who also made use of older sources; a general map of the east coast of Greenland, drawn by Koldewey and Hegemann, with the use of the original maps of Graah, Scoresby and Clavering-Sabine; three maps drawn by J. Payer, one of the east coast of Greenland, based upon reconnoitring works done by the astronomers of the expedition, Borgen and Copeland, one of Pendulum Island and one of Tirol Fiord. Further, there is a general map of the northern part of the east coast of Greenland, discovered in the course of a sledge journey, as well as a sketch, made by the crew of the "Hansa", on their drift in the ice and representing the east coast between lat. 66° 30′ and 67° N. comprising Horror Bay and a sketch of the coast from Iluileq round Cape Farewell to Frederikshaab. Of place-names should be mentioned King Wilhelm Land, Koldewey Island, and Dove Bay inside Cape Bismarck. For the sketch of a geological map of the south point of Greenland, made in 1873 by the German Dr. G. Laube, the outline is taken from Graah, Rink and Hegemann.

The cartographic work is continued in a northern direction, as appears

from the maps accompanying C. H. Davies' description of the North American Expedition 1871—73, under the leadership of C. F. Hall. The distance from Washington Land to about lat. 82° N. is mapped, and the outline of the already discovered country has been improved. Of new place-names should

Fig. 17. Nares' Map.

be mentioned Hall Land, a peninsula north-east of Washington Land and divided from the latter by a deep fiord, Petermann or South-Fiord; further, Hall Basin between Hall Land and Grinnell Land and Robeson Strait between Hall Land and Grant Land.

The English North-Polar Expedition 1875—76 under Capt. Nares further extended our knowledge of the northern waters. As a supplement to Nares' description of the expedition there is a carefully executed map (fig. 17),

as the sources of which are given Kane, Hayes and Hall, for the coast of Grinnell Land and *Greenland north of lat. 82° N.* as well as for the west coast of Robeson Channel, Kennedy Channel and Smith Sound, this map being based upon the observations of the expedition. Between lat. 82½ and 83° N. the position of a few islands is sketched, and north-east of Hall Land a deep fiord (Sherard-Osborn Fiord) is indicated. In a reproduction of the map in Petermann's "Mittheilungen," 1876, the hypothesis of Petermann is set forth, *viz.* that Greenland should "send an arm up above the North Pole."

While fully acknowledging the energetic efforts made on the part of Denmark in order to give a true representation of Greenland, it cannot, on the other hand, be denied that owing to the large extent of the country and the deep and greatly branched incisions of the coast the achievement of this result would necessarily require further researches. On the initiative of the Commission founded in 1878 in Copenhagen for the "carrying on of geological and geographical researches in Greenland" (the Greenland Commission), various expeditions were sent out, and the work done by the latter was of the greatest importance towards the preparation of a correct and detailed map of Greenland. These systematic and methodical investigations, commenced as early as in 1876, supply an extremely valuable and complete cartographic material, based upon careful astronomical observations as well as upon comprehensive works of triangulation and levelling. For the west coast the determination of longitude is based upon the results of Graah, Falbe, Bluhme, Nordenskiöld and Inglefield, but owing to their great number only a cursory description can be given of these maps. From the period 1876 to 1881 date the following:

A geognostic map of part of the Julianehaab District, prepared in 1876 by G. F. Holm, R.N. and K. J. V. Steenstrup.

Three maps of the west coast, lat. 61° 20′—62° 20′, 62° 15′—64° 30′, 66° 55′—68° 20′ N., as well as a map of the inland ice east of Frederikshaab Iceblink and its immediate surroundings, based upon the surveys of J. A. D. Jensen in the years 1877—1879.

Maps of the west coast lat. 69° 10′—72° 35′ N., surveyed in 1878—1880 by K. J. V. Steenstrup and R. R. J. Hammer.

Chart of Denmark Strait by Mourier, representing the route of the Danish man-of-war "Ingolf" in 1879, as well as various indications of depths.

Map of the southern part of Greenland, lat. 61° 15′ on the west coast to lat. 60° 30′ N. on the east coast, surveyed in 1880—81 by G. F. Holm.

Whereas Danish expeditions worked in the south, the development of the Greenland map towards the north once more profited by the efforts of international Polar exploration, in that J. B. Lockwood, a member of the American Greely Expedition, in 1882 traversed and mapped the coast from

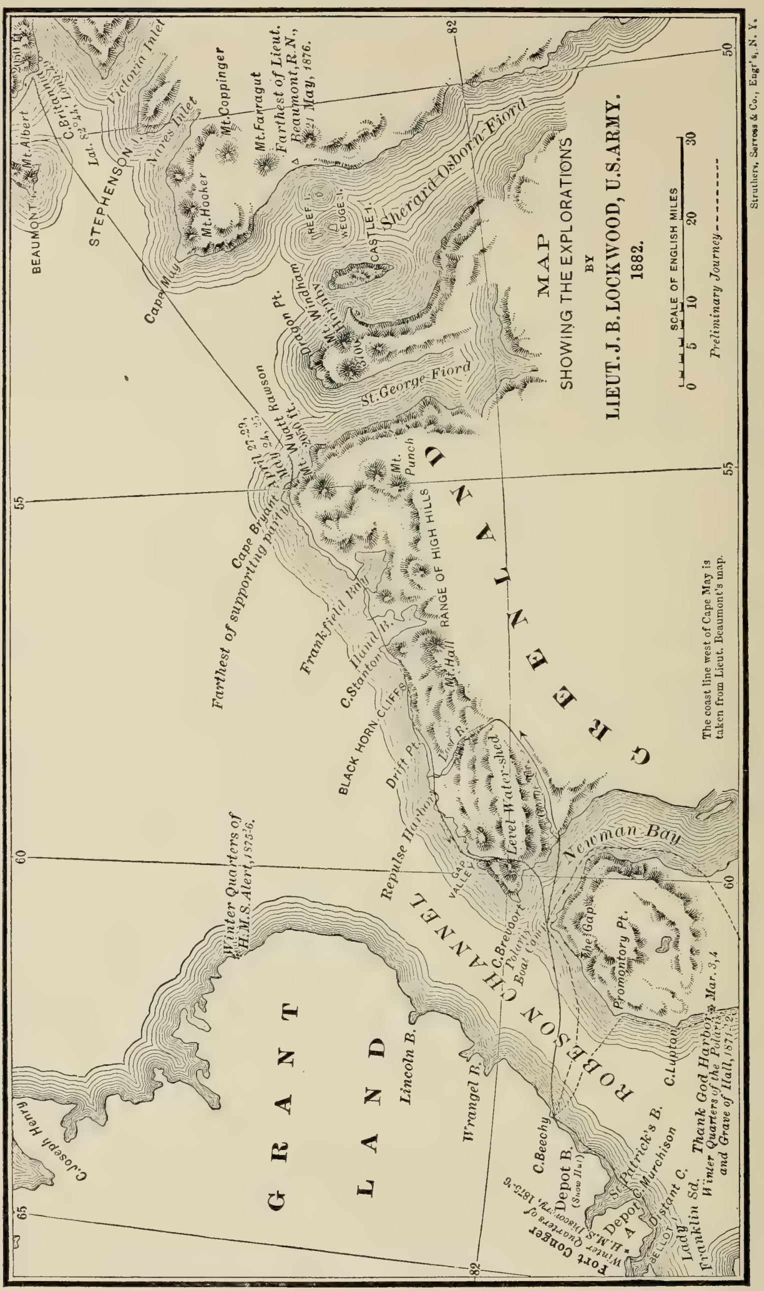

Fig. 18. Lockwood's Map.

Sherrard-Osborn Fiord to lat. 83° 24′. N., thus establishing the connection with the map of Nares (fig. 18).

The Nordenskiöld Expedition 1883 supplied three maps, drawn by the topographer Kjellström, one of which represents Egedesminde and its surroundings, as well as the profile of the investigated part of the inland

ice, one King Oscar's Harbour on the east coast and one "the whole of Greenland, south of lat. 78° N., based upon the most recent, principally *Danish*, sources."

As the result of the continued survey work carried on by various expeditions, sent out by the Greenland Commission in the period 1881 to 1890, to the west as well as to the east coast (the "Konebaad Ekspedition" under the command of G. F. Holm) the following valuable maps appeared:

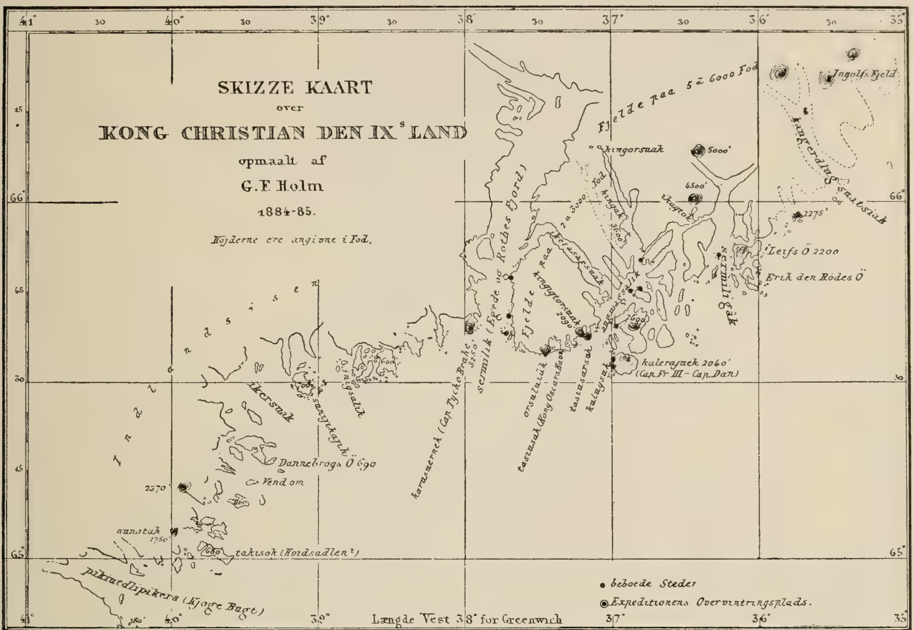

Fig. 19. G. F. Holm's Map.

Map of North Greenland from lat. 68° 20′—70° N. surveyed in 1883 by R. R. J. Hammer, with geological signatures by Sylow.

Map of the west coast lat. 65° 10′—69° 10′ and lat. 64°—65° 30′ N. surveyed in 1884 and 1885 by J. A. D. Jensen. By means of these surveys it is proved that the map-sketches of Hall from 1605 in the main show a correct conception. Thus Queen Anne Cape corresponds with Simiutaq, King Kristian Fiord with Itivdleq Fiord, Mount Cunningham with Qáqatsiaq and Breade Ranson Fiord with Ataneq Fiord.

Map of the southernmost part of the east coast as far as lat. 63° 45′ N. prepared from the surveys made on the "Konebaad" Ekspedition (1883—1885) by G. F. Holm and V. Garde, with geological signatures by P. Eberlin. The map is a revised and extended new edition of Graah's map.

Map of the Angmagssalik region with a map of the east coast from lat. 63° 20′—66° 25′ N. (fig. 19), based upon the surveys made in the course of the same expedition by G. F. Holm (1884—85).

The map is accompanied by a sketch of the east coast from lat. 66°—68° 45′ N. drawn on the strength of information given by the people of Angmagssalik and with the help of the observations from "Hansa" and "Ingolf." The longitude is referred to a direct determination of a station at Angmagssalik, and the map is extremely important by the picture represented of the distance north of Graah's turning point, hitherto only known through conjectures, and by the mapping of the large fiord system north of Angmagssalik.

Map of the west coast from lat. 72° to 74° 35′ N., based upon the surveys undertaken in 1886 and 1887 by C. H. Ryder. The longitude of this map is referred to Upernivik, which is directly determined.

Further, on the expedition sent out by the Greenland Commission soundings were undertaken at various anchorages, and in the years 1884, 1886 and 1889 bathymetrical surveys were made, on the initiative of the Danish Admiralty, at anchorages and farther out at sea. These surveys were made from the man-of-war schooner "Fylla," under Captains Normann, Braëm and Wandel respectively, and the complete material forms the basis of charts prepared by the Royal Hydrographic Office and upon the initiative of the Royal Greenland Trading Company. In 1887 the Hydrographic Office issued a chart of the west coast from Arsuk to Holsteinsborg lat. 61°—67° N. with a special map (No. 145); in 1888 a map of the west coast of Greenland from Holsteinsborg to Upernivik (No. 146), with environs, two sheets, south of lat. 73° 45′ N. (No. 147), and in 1883 a map of the southern part of Greenland with a special map (No. 148). These maps are constantly brought up to date and published until the present time. Fig. 24 represents map No. 147, carried up to 1925. In 1887 the Royal Greenland Trading Company issued charts of Syd-Bay Harbour, the Harbour at the Nepisat Islands, Egedesminde, Ritenbenk, Christianshaab and Sukkertoppen, based upon the surveys of the above-mentioned Danish naval officers.

As a supplement to Fridtjof Nansen's "Paa Ski over Grönland" (1888—89) there is a map of Umîvik with environs, partly based upon the map of G. F. Holm; another map of the western descent from the inland ice, as well as a map representing the travelling route of the expedition and the transverse section of the inland ice, which is of the greatest importance towards the knowledge of the interior.

The expeditions sent out by the Greenland Commission in the period 1890—1900, among which the *Carlsberg-Fund Expedition* to East Greenland (1898—1900) under G. C. Amdrup, gave rise to the following maps:

Map of the east coast between lat. 69° and 74° N., based upon the surveys of C. H. Ryder, the East Greenland Expedition (1891—92). The map derives its chief importance from the fact that it is an accurate representation of the Scoresby Sound fiord system; the remainder of the coast is

partly taken from Scoresby and partly laid down by means of bearings and angles taken from the ship of the expedition on its way south.

Three maps of the Julianehaab District, two from the surveys of T. V. Garde during the summer of 1893, and one from the surveys of C. Moltke during the summer of 1894. The longitude of the maps is indicated with Julianehaab as the standard meridian.

Map of the west coast from lat. 67° 20′ to 69° 20′ N., surveyed by Frode Petersen, The map is supplied with the surveys of Jensen and Hammer in 1879 and 1883.

Map of the east coast, King Christian IX's Land from Angmagssalik to Depot-Island, prepared from Holm's map as well as from surveys undertaken by G. C. Amdrup in the course of the Carlsberg-Fund Expedition (1898—99).

Map of the east coast from lat. 65° 55′ to 68° 10′ N., surveyed on the same expedition by G. C. Amdrup 1898, 99 and 1900.

Fig. 20. Map of the Amdrup Expedition.

Map of the east coast from lat. 67° 45′ to 69° 25′ N., surveyed in the course of the same expedition by G. C. Amdrup, 1900.

With the two latter maps (fig. 20) the great goal had been achieved, *viz.* the mapping of the coast between *Angmagssalik* and *Scoresby Sound*, which had hitherto only been known from observations taken far out at sea. The longitude is referred to Amdrup's astronomical determination of a station at Angmagssalik. In order fully to realize the importance of these charts towards completing the map of Greenland, which for the latter part of the coast was subjected to all sorts of conjectures, it should be noted that Cape Grinnell is situated about 1° 20′ farther west than indicated by Blosseville's observations.

Map of the east coast from lat. 69 °20′—72° 20′ N., based upon surveys made during the same expedition by J. P. Koch in 1900. Part of the coast is taken from Scoresby, Ryder and Nathorst, though modified according to

the observations of Koch, wherever such modifications were necessitated by minor deviations. From the Nathorst Expedition (1899) there is a map of Franz-Joseph Fiord, representing the latter as a huge system of fiords, communicating with Davy Sound through King Oscar Fiord.

It may be said with full justice that the maps of Greenland south of about lat. 72° N. at the end of the 19th century, from the Danish Egede type through the expeditions of Graah and the Greenland Commission, have developed into a *true and correct* representation of Greenland.

Within the period 1890—1900 the following special maps were issued by the Royal Greenland Trading Company:

Maps of Upernivik, Julianehaab, Kronprinsens Eiland and Godhavn, prepared from the surveys of Danish naval officers, as well as in 1895 the work which is of such great importance for the navigation of Greenland, *viz.* V. Garde's "Vejledning til Besejling af Kolonierne i Vestgrønland." This book is provided with numerous special maps and landmarks and is based upon information obtained from Graah, Normann, Wandel, M. and C. Bang, Moltke and others, and also upon the observations made by the author in the course of nine summers spent in the waters of Greenland.

The influence exercised upon the map picture of North Greenland by the discoveries of Robert E. Peary, 1892—1900 appears, *inter alia*, from a map of the regions round Navy Cliff, an improved map of the Cape York District, as well as a map of Baffin Bay to Lincoln Sea, Polar Regions, showing the recent discoveries by R. E. Peary, C. E. U. S. A., 1903.

The maps supply an essentially correct picture of the north coast as determined by Peary, but also show his conception of northernmost Greenland as an island divided from Greenland proper by a narrow sound, the Peary Channel, which gives rise to a special North-Greenlandic type, the Peary type.

In 1905 E. Astrup, a member of Peary's expedition, made a sketch of Melville Bay, which was further mapped by the "Literære Grønlandsekspedition" 1902—1904.

The expedition of the Duke of Orleans contributed a map of the east coast from lat. 76° 30′—79° N., which, in particular north of Ile de France, must be looked upon as a mere sketch.

Account has been rendered elsewhere of the valuable contributions of the "Danmark" Expedition, 1906—08, towards the cartography of the still unknown parts of the east coast. Here it is only to be mentioned that it supplied the following charts and maps, based upon triangulations and astronomical surveys. The longitude is referred to a direct determination of a station at Danmark Harbour:

Map of Danmark Harbour and surroundings, surveyed by C. B. Thostrup and others. Soundings after A. Trolle.

Maps of North-east Greenland from lat. 76° 9′ to 78° N., Queen Louise's Land and Germania Land.

Maps of North-east Greenland, southern sheet: *Pendulum Island-Lambert Land* lat. 74° 30′—79° 10′ N.; northern sheet: *Lambert Land—Peary*

Fig. 21. Peary's Map, 1903.

Land, lat. 78° 45′—83° 30′ N. The southern sheet is the result of the following travels: that of Koch to Skærfiord and Germania Land, of Trolle to Skærfiord, of Hagen to the southern part of Jökel Bay, of Bidstrup to Dove Bay, of Bertelsen to Queen Louise Land and of C. B. Thostrup to Ile de France. Whereas the southern sheet must be considered an improvement of earlier maps, the northern sheet for the greater part comprises hitherto unknown coast stretches. In this sheet Danmark Fiord, Hagen Fiord and

Independence Sound are taken from other sketches by Hagen; the remaining coast line is determined by Koch, and south of "Amdrup Land" also by C. Thostrup and Bidstrup. The name Independence Sound indicated that the Peary type was retained, seeing that as yet nothing was known of the report of Mylius-Erichsen, containing the statement that the *Peary Channel did not exist.* Fig. 22 shows the part mapped in the course of the expedition and further indicates, in dotted lines, the outlines of earlier maps. The "Danmark" Expedition forms a worthy conclusion to the task set by Sir Clemens Markham, *viz. to encircle Greenland.*

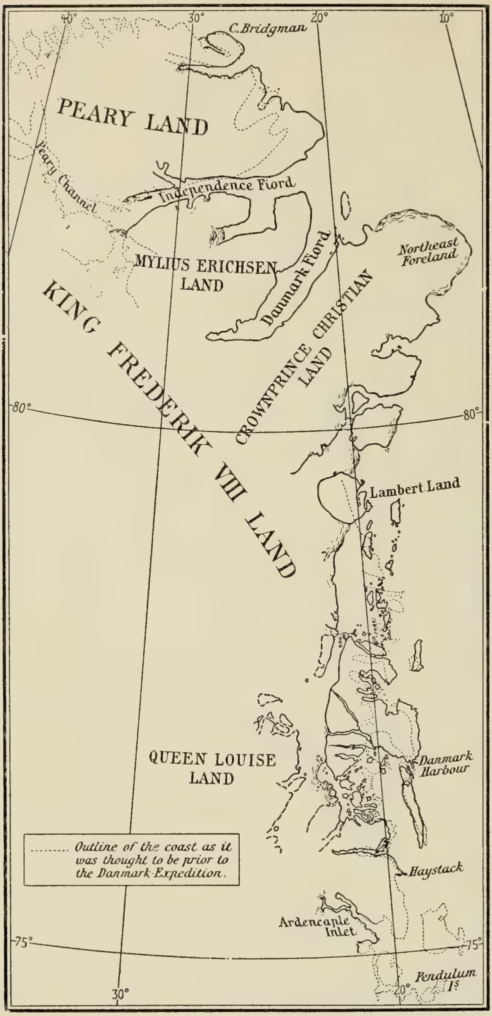

Fig. 22. Map of the "Danmark" Expedition.

As to the astronomical observations it should be noted that the determination of Haystack, which by means of triangulation was connected with the station at Danmark's Harbour, yielded a longitude 2′ 36″ farther west than that of the Germania Expedition in 1870, which might go to prove the correctness of Wegener's theory of the movement of Greenland towards the west (M. o. Gr. XLVI. p. 240). Together with the investigation of the hitherto unknown coast stretches endeavours were made to provide good charts of various harbours on the west coast, where Borg undertook surveys, resulting in charts of Nûgssuaq and environs, 1907, Faltings Harbour, with the entrance to the latter, 1907, Godthaab Fiord, the entrance to it, Rink's Harbour 1909, Coppermine Bay 1909—1910 and Borg's Harbour 1910. These charts were subsequently published by the Royal Greenland Trading Company.

From the Alabama Expedition 1909—12 dates a map of the transversed part of the inland ice, with indications of heights as well as a map of the Danmark Fiord. The maps, which are drawn by the leader of the ex-

pedition, Einar Mikkelsen, are based upon astronomical observations and represent a somewhat modified and more detailed picture of the fiord, besides showing certain alterations in individual mountain masses.

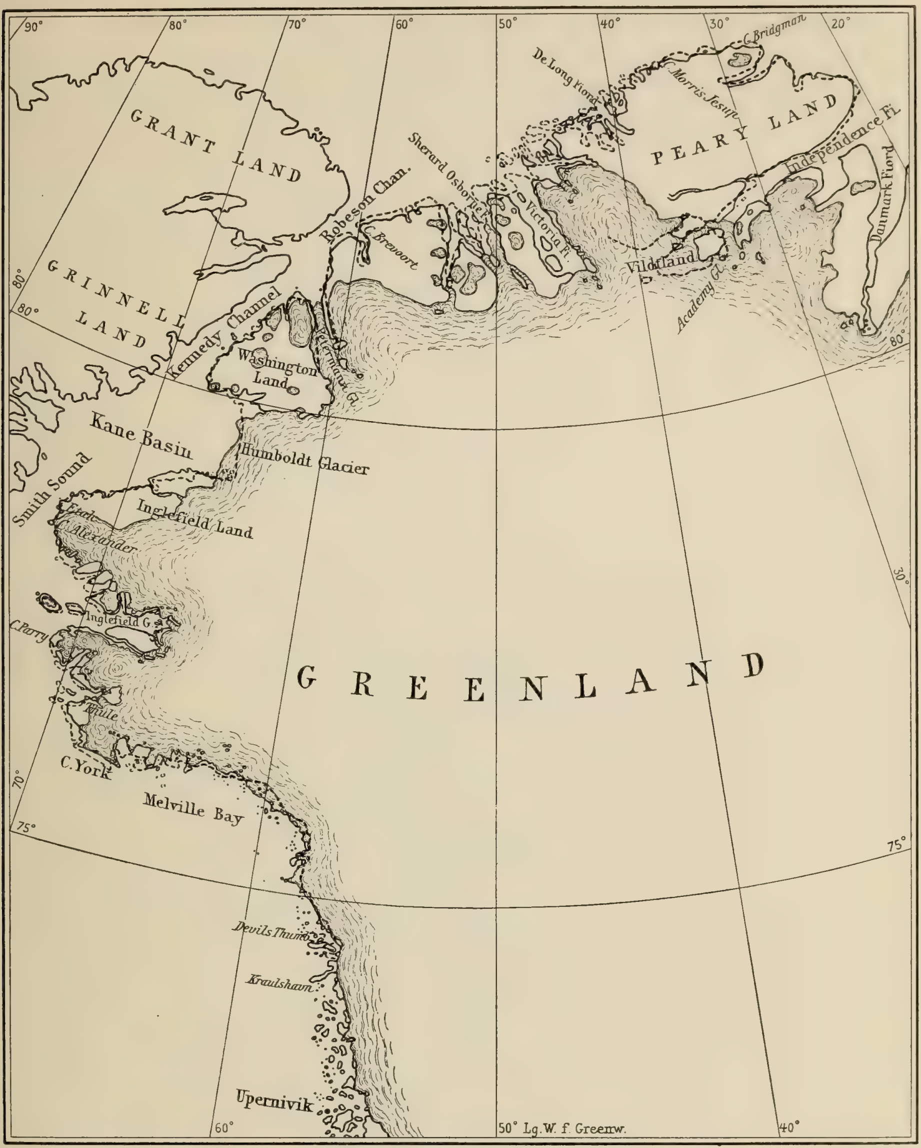

Fig. 23. Lauge Koch's Map, 1926.
The dotted line indicates the shore-line after Knud Rasmussen's Map, 1919.

The first Thule Expedition, 1912, contributes a map of the country connecting Peary Land and Greenland, which map is drawn by Peter Freuchen in corroboration of the correct report of Mylius-Erichsen, found

in Danmark Fiord by E. Mikkelsen—or, in other words, to establish the *North Greenland type of Mylius-Erichsen*, and, further, a map of the route followed, to elucidate the profile of the inland ice.

Quervain's journey in 1912 across the inland ice from Ritenbenk to Angmagssalik, as well as the Danish voyage of investigation, under F. P. Koch, across the inland ice from Danmark's Land to Pröven, supply maps of the routes followed and information of the profile of the country, thus largely extending the knowledge of the inland ice. To the latter is further due a detailed map of Queen Louise Land.

Of the maps issued by the Royal Greenland Trading Company should be mentioned, from 1915, a detailed map of the east coast from lat. 64°—60° 30′ N. prepared after G. F. Holm, C. G. Amdrup and C. Kruse, as well as a number of special maps from 1923. Further is to be noted the atlas published in 1921 by the Greenland Commission as a supplement to the work "Grönland," this atlas containing general and special maps of the inhabited districts; also as relating to the position of Greenland the astronomical observations commenced in 1922 by Colonel P. Jensen, as far as the determinations of longitudes are concerned for the first time with the aid of wireless signals, with the object of demonstrating the above-mentioned Wegnerian hypothesis.

As the cartographer of the second Thule Expedition 1919, and a leader of the Bicentenary Expedition 1921—23, Lauge Koch prepared a number of maps of North Greenland, comprising the distance from the northern boundary of Upernivik to Danmark Fiord. From the former expedition originates a map of Melville Bay as well as of North Greenland from lat. 81° to 83° 25′ N. and long 38° to 25° W.; from the same expedition maps of the remaining coast stretch, of which special mention should be made of: "Map of the north-coast of Peary Land from the de Long Fiord to Fr. Hyde Fiord;" "Map of the *southern Peary Land* from Schley Fiord to Wandels Valley;" "Map of the regions round the head of Independence Fiord," as well as maps of the southern part of Victoria Fiord. These maps are based upon independent observations, astronomical and otherwise, and as the earlier maps of the distance in question must in the main be looked upon as sketches, the contributions of Lauge Koch are very important, partly as a revision and improvement of the already existing map (fig. 23), and partly by supplying maps of regions up till then entirely or partly unknown.

The map of the southern Peary Land furnishes an explanation of the hypothesis of Peary and replaces the *North-Greenland types* by a true picture.

The Bicentenary Expedition completed the solution of the great task, *viz.* the making of an essentially correct picture of Greenland. With the exception of Franz-Joseph Fiord and its surroundings the outlines of the present map of Greenland are, in the main, laid down by Danish expeditions. Thus, while fully acknowledging the great importance of the work of foreign

exploration, one may say, with full justice that a Dane, Clavus, was the originator of the first Greenland type and that Danes prepared the true cartographic representation of Greenland.

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THE GEOGRAPHICAL SITUATION OF GREENLAND

BY

M. VAHL, Ph. D.

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Greenland is the largest island in the world, being in size only surpassed by the four land-masses which, by established custom, are termed continents.

The most southerly point of Greenland is Cape Farewell, which is situated in lat. 59° 46′ N., or farther south than Oslo and the Shetland Islands. That southern Greenland, by natural conditions and means of existence, nevertheless belongs to the Arctic region is principally due to the ice-filled seas which surround the country and lower the summer temperature, to the detriment of vegetation and, consequently, also of animal and human life.

The most westerly point is Cape Alexander at Smith Sound (ca. lat 78° 10′ N. long 73′ W).

The northern point of Greenland is Cape Morris Jesup, the latitude of which Peary determined at 83° 39′. A little to the east of the latter lies Cape Bridgman, the most northerly point of the "Danmark" Expedition (lat. 83° 29′ 17″ N). The most easterly point of Greenland is Northeast Foreland (lat. 81° 21′ N., long. 11° 33′ E.) the discovery of which is due to the "Danmark" Expedition. Thus Greenland extends over about twenty-four degrees of latitude, while its area is about 2.2 million km². Owing to its situation towards the north, the interior of the country, which everywhere rises to a considerable altitude above sea level, is covered by a huge ice cap. The latter covers nearly nine-tenths of the area of Greenland, and from here tongues of ice move to all sides. In some places this inland ice reaches right out to the sea, but in most places there is between it and the coast a broader or narrower outer land. The area of the latter[1], along the west coast, is estimated at 116,000 km² from Cape Farewell to Melville Bay; along the north coast from Melville Bay as far as lat. 80° N. on the east coast at 99,000 km² to the south of this; along the east coast to Cape Farewell at 98,000 km², or a total area of 313,000 km². The coast of the outer land

[1] Hammer: Medd. om Grønl. LX, p. 1.

is almost everywhere greatly incised with fiords, many of which extend as far as the inland ice. Therefore, the length of the coast is very great. A measuring of the length of the coast, undertaken on a map to a scale of 1 : 2,000,000 yields, in the case of the west coast, from Cape Farewell to Melville Bay, an extent of 20,098 km, while the north coast, from Melville Bay to Northeast Foreland, measures 7627 km and the east coast from Northeast Foreland to Cape Farewell 16,360 km. From this it appears that the colonized part of the west coast is far more jagged than the remaining coast, but on the other hand the greatest and most widely branching fiords of Greenland, *viz.* Scoresby Sound and Kaiser Franz Joseph Fiord, are situated on the east coast between lat. 70° and 75° N.

As an immense plateau Greenland rises between four huge ocean basins: the Polar Sea to the north, the Greenland or Norwegian Sea to the east, the Atlantic Sea to the south and Baffin Bay to the west. North of the latter Greenland is divided from Ellesmere Land by a number of ocean arms, *viz.* North Water, Smith Sound, Kane Basin, Kennedy Channel, Hall Basin and Robeson Channel. The depth of these waters is very imperfectly known, but it seems as if only farthest south, in North Water, it exceeds 400 m. Thus Greenland is only divided from the Canadian-Arctic Archipelago by comparatively shallow marine areas, which form the connection between the shelves of the American Continent and those of Greenland.

The four deep ocean basins are divided from each other by three submarine ridges which from Greenland extend towards the land-masses situated beyond the seas. Thus, from the north-eastern corner of Greenland a submarine ridge has been identified in the direction of Spitzbergen, which seems to be a submerged part of the Caledonian Range, the contemporaneity of which with the folding of the mountains of the north coast of Greenland was demonstrated by Lauge Koch. In Denmark Strait there is also a submarine ridge, extending between Greenland and Iceland and then farther across the Faroes to Scotland. The whole of this ridge is characterized by its volcanism, which on Iceland has not even settled. On the east coast of Greenland the volcanic area recurs south of Scoresby Sound. In the interior of Greenland everything is covered by the inland ice, but on the west coast the Tertiary basalt streams recur on Disko Island and on the peninsulas to the north of this island.

From the great depths of the Atlantic a bay extends up between Labrador and the west coast of Greenland. In the southern part of this bay oceanic depths still occur, in Davis Strait, however, succeeded by a submarine ridge, which connects Greenland with Baffin Land. North of this ridge the bottom of the sea in Baffin Bay again declines to fairly great depths.

Greenland is situated in the place where the American Continental block approaches most nearly to the European one, and therefore Greenland has been drawn into the discussion on possible land connections be-

tween the two continents. The existing relationship between the fossil and the present faunas and floras can, however, in the main be explained without difficulty by the land connection, which several times within the history of the continents has been established between Alaska and East Asia. In this

Environs of Greenland.

manner it has been possible for species of animals and plants to be exchanged and to extend farther over the two continents, as far as the climate suited them. There are, however, a few groups of animals and plants which occur in America and Europe, but are lacking in Asia. For the latter it is likely to suppose a former connection by land between Europe across Greenland to America, and the ridge on which Icelánd and Greenland are situated would, as a matter of fact, by a moderate uplift be altered to such

a land bridge composed of a number of close-lying islands, only divided by narrow ocean arms.

Whereas former adherents of the hypothesis of land connections in the past have generally supposed them to have been brought to an end by the land-masses, which formed the connection, subsiding to greater or lesser depths below the level of the sea, Frank B. Taylor and A. Wegener[1] have made an attempt to explain the separation of the formerly continuous land-masses by vertical displacements, so that the different continents and islands move away from each other.

This theory has been opposed from various points of view. As far as Greenland is concerned, Kober[2] has maintained that there is no petrographic resemblance between East Greenland and Norway, nor can Baffin Land be regarded as a separated part of Greenland. As against this, reference may be made to the incomplete knowledge of the petrography of East Greenland and Baffin Land. In support of the hypothesis of Wegener it is stated[3] that the determinations of longitudes in Greenland show a displacement towards the west of 420 m within the period from 1823 to 1870 and of 882 m from 1870 to 1922. Owing to the inaccuracy of the old observations, it is not possible to place absolute reliance in the theory that the apparent alterations in the longitude should be founded upon facts. In 1926 a permanent station for determinations of position was established at Qornoq, east of Godthaab. Here accurate observations will be undertaken, so that in a few years it will be possible to determine whether the longitude actually changes.

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[2] Petermanns Mitteilungen. 1926.

[3] I. P. Koch: The Drift of North Greenland in a Westerly Direction. Medd. o. Gr. XLVI pp. 240—286. 1917.

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THE WATERS ROUND GREENLAND

BY

J. N. NIELSEN, Ph. D.

I. BATHYMETRICAL FEATURES.

Our knowledge of the depths of the waters round Greenland is, as yet, rather incomplete, which is a natural result of the great extent of the sea and the fact that the greater part of the coast is extremely difficult of navigation. The accompanying chart (fig. 1) which is meant to give a summary of depths along the coasts of Greenland, consequently makes no claim to exactness in details, but must be taken as an expression of what is known, at the present time, of bathymetrical conditions in the waters round Greenland.

This chart, as far as is known the first of its kind, has been prepared from various sources, *viz.* for the northern part of the east coast from the bathymetrical charts of Helland-Hansen and Nansen in their work on the Norwegian Sea (1909), with due regard to the soundings undertaken by the "Danmark" Expedition, as well as by Nathorst, Amdrup and Ryder in the fiords and the vicinity of the coast. From Scoresby Sound to Cape Farewell there are only extremely few soundings near the coast, and the 200 metre curve is, where it has been laid down, rather hypothetical. As far as the waters south-west of Iceland are concerned, the charts of depths prepared by Wandel (1898) form the basis of the present chart, whereas the curves along West Greenland have been drawn from the maps prepared by the Danish Hydrographic Office, with various alterations undertaken on the strength of the soundings made by the present writer in the course of the "Tjalfe" Expedition to West Greenland in 1908—09. As far as Smith Sound, Kane Basin and the Kennedy and Robeson Channels are concerned, the data at hand are too sparse to allow of the laying down of the 200 metre curve, and off the north coast of Greenland the depths are still entirely unknown.

The credit for having charted the last unknown part of the east coast of Greenland north of lat. 76° N. is—as is well known—due to the "Danmark" Expedition. By the efforts of this expedition it was proved

that the northern part of the coast extended considerably farther east than was formerly supposed, and that the strait between Northeast Greenland

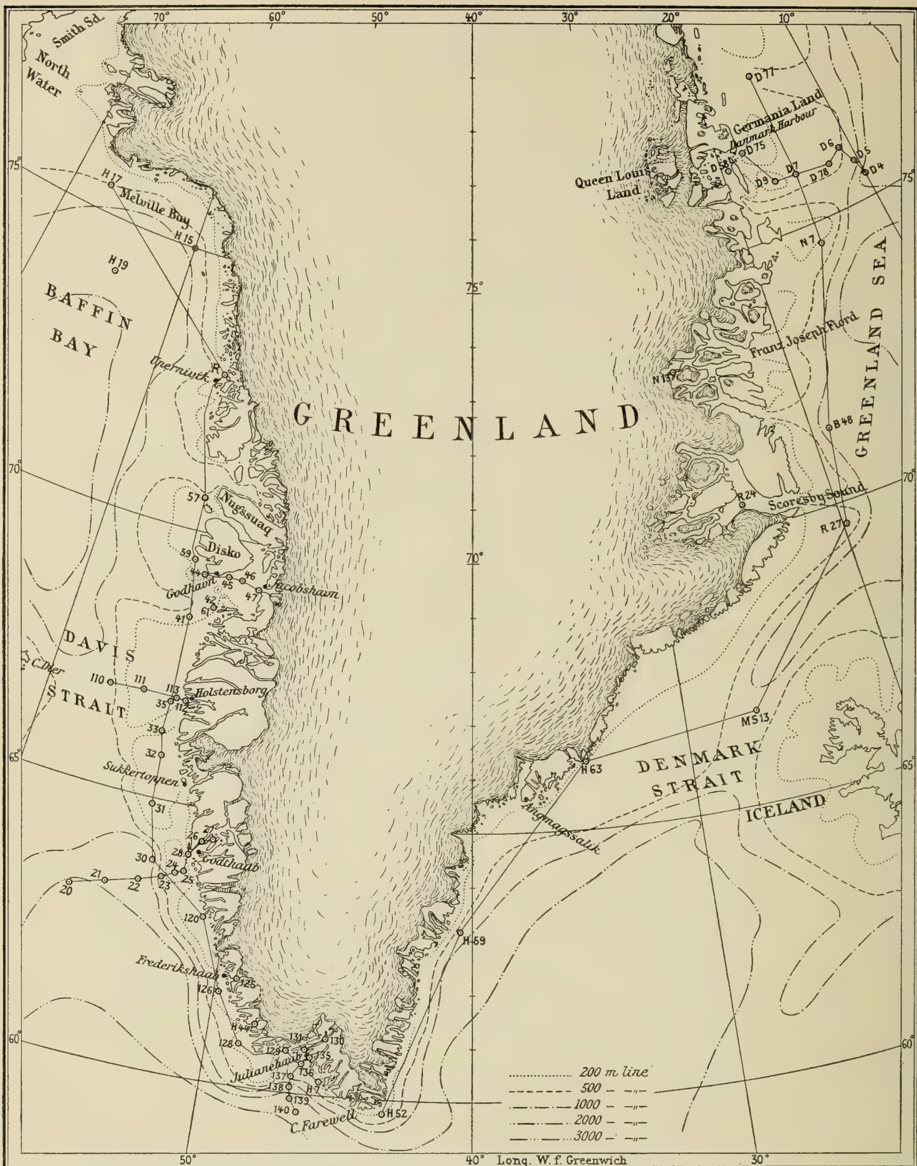

Fig. 1. Map of the waters round Greenland indicating the stations mentioned in the text.

and Spitzbergen was, consequently, much narrower than expected. From the western half of the latter no single sounding is at hand, whereas soundings in its eastern half show a submarine ridge extending from Spitzbergen

in a north-westerly direction. From the existing soundings, the deviating hydrographical conditions of the Polar Basin and the deep of the Norwegian Sea, Helland-Hansen and Nansen (1909, p. 77) arrive at the conclusion that this submarine ridge connects Spitzbergen with Northeast Greenland; they estimate the maximum depth of this ridge at between 700 and 800 m. and suppose the depth to decrease in the direction of Greenland, where, perhaps, it only amounts to 200—400 m. As mentioned above, no information is, however, at hand regarding this matter.

South of the Greenland-Spitzbergen Ridge the bottom slopes gradually towards a basin with depths of 3000 m. or more, by the Norwegian oceanographs called the "Greenland Deep." The latter is situated at a considerable distance from the coast of Greenland north of lat. 75° N., there being along it an extensive coast shoal with depths of less than 500 m. The surface of this shoal, according to the soundings of the "Belgica" and "Danmark" Expeditions, is rather irregular and intersected by several fairly deep channels, with depths of 300—400 m. and separated by banks, less than 200 m. deep.

The slope towards the Greenland Deep is fairly even, whereas the continental shelf in about lat. 73°—74° N. falls steeply from 500 m. to depths of more than 2000 m. (according to Mohn the "German Deep"). Furthermore, the coast shoal in this place becomes narrower than north of lat. 75° N., but still there are a number of extensive banks with depths of less than 200 m.

Within the three large systems of fiords, *viz.* Franz Joseph Fiord, Davy Sound and Scoresby Sound, the depths exceed 500 m; in the first mentioned Åkerblom (1914, p. 17) at his St. XIV, registered 763 m., and in the neighbourhood of this place the second German Polar Expedition did not reach the bottom with a 940 m. wire. Whether Davy Sound and Scoresby Sound continue through the coast shoal with depths exceeding 500 m., as indicated on the chart, is perhaps uncertain; as far as Franz Joseph Fiord is concerned the depth, as we shall revert to later on, is undoubtedly not so great above the coast shoal off its mouth.

South of Scoresby Sound the coast is less incised, and the coast shoal is considerably narrower than farther north. From the Greenland Deep there is, in this place, an offshoot with depths of 1400—1500 m. passing in the direction of Denmark Strait: the latter (the Iceland—Greenland Channel) bears a striking resemblance to the Faroe—Shetland Channel, which from the deep of the Norwegian Sea extends, also in a south-westerly direction, between the Faroe Plateau and the Shetland Islands.

In Denmark Strait, between Iceland and Greenland, the depth is comparatively small. As is well known, we meet in this place the North-Atlantic transversal ridge, extending from the North Sea plateau, across the Faroe Bank to the Faroes (the Wyville Thomson-Ridge), from the Faroes to

Iceland (the Faroe-Iceland Ridge) and from there, under the name of the Iceland-Greenland Ridge, to Greenland. Whereas the maximum depth across the Faroe-Iceland Ridge is nearly 500 m. and across the Wyville-Thomson Ridge about 575 m., it is in Denmark Strait nearly 600 m.; the deepest channel lies nearest Iceland, whereas, off the coast of Greenland, there is a rather extensive coast shoal with depths of less than 350 m.

On the south side of Denmark Strait the bottom, in the middle of the strait, falls rather steeply to depths of more than 2000 m., and also to the east of South Greenland the depth exceeds 3000 m. As mentioned above, there are only very few soundings from the neighbourhood of the coast, and our knowledge of the extent of the coast shoal is, therefore, a very slight one. In about lat. 63° N., however, the 500 m. curve passes very close to the shore, which appears from Hamberg's sounding of 750 m. in lat. 63° 10′ N., long. 40° 35′ W. (Hamberg 1884, St. 59. p. 13).

South of Cape Farewell, the southern point of Greenland, the depth exceeds 2000 m. at a distance of about one degree of latitude from the shore. Nevertheless, there is a suggestion of a submarine continuation of Greenland, seeing that there is a ridge running towards the south and dividing the deep basin south of Greenland into a smaller easterly and a larger westerly part; the depth of this ridge, however, which at first appears distinctly at depths exceeding 2000 m., comparatively quickly increases to above 3000 m. towards the south.

The west coast of Greenland as compared with the east coast is distinguished by a far greater quantity of incisions. Along the whole coast, as far as Holsteinsborg, there is a continuous belt of skerries with an infinitude of islands, and numerous fiords project inland. As the more important of the latter may be mentioned the fiords round Julianehaab, the Godthaab system of fiords, North and South Strömfiord, Disko Bay with the Vaigat and, finally, Ũmánaq Fiord.

Outside the belt of skerries, along the west coast of Greenland, there is a number of more or less separated coast banks with depths of less than 200 m. From Cape Farewell to Godthaab the coast shoal is, however, somewhat narrow, with the exception of the bank extending southward from Nunarssuit. On the whole of the above-mentioned stretch the continental shelf falls very steeply from 200 m. to depths of more than 2000 m.; to the south-west of the Nunarssuit bank depths of even more than 3000 m. are obtained at a short distance from the shore.

Inside the Nunarssuit shoal the deep water sends off a bay in the direction of the mouth of Bredefiord, where the "Tjalfe" Expedition found a depth of 685 m., and farther up the fiord still greater depths have been registered. It is, however, hardly probable that the 500 m. curve extends all the way up the fiord across the coast shoal, even though the hydrographical conditions, as will subsequently appear, favour the supposition that this fiord is

being continued as a submarine fiord across the coast shoal, seeing that in the case of most of the fiords, even though they are continued across a depression in the coast shoal, there is as a rule a threshold with smaller depths than in the interior of the fiord. It must, however, be borne in mind that the sea bottom off most of the mouths of the fiords is very uneven, for which reason it is, as a rule, not possible to establish the maximum depths of the thresholds on the basis of the soundings at hand.

North of Godthaab the coast shoal increases in breadth, and by submarine fiords is divided into three banks: Fylla Bank and Little and Great Hellefiske Bank; on the greater part of Fylla Bank and the interior half of Great Hellefiske Bank the depths are about 50 m. Of the above-mentioned submarine fiords the one dividing Fylla Bank and Little Hellefiske Bank is presumably the deepest and extends, with depths of about 400 m., inside the latter bank in the direction of Sukkertoppen.

Whereas the west side of Fylla Bank still slopes rather steeply, there are comparatively small depths west of Great and Little Hellefiske Bank; here a continuation of the formerly mentioned North-Atlantic Ridge is met with, running across the narrowest part of the Davis Strait and uniting Greenland with Baffin Land. The maximum depth of this threshold is not known for certain, but it presumably amounts to about 600 m., or perhaps a little more. North of this submarine ridge, in the south-western part of Baffin Bay, there are again depths of about 2000 m., whereas the depths are considerably smaller on the east side, and west of Disko Island there is a large shoal with depths of less than 200 m.

Between Great Hellefiske Bank and the Disko shoal a deeper tract with 300—400 m. extends in the direction of the mouth of Disko Bay, where some small groups of islands are situated. In the interior of Disko Bay the depth is very nearly 400 m. except on the Jacobshavn Icebergbank (250—300 m). In the strait between Ritenbenk and Disko Island the depth increases to about 550 m. but presumably decreases somewhat through the Vaigat, the depth of which, however, is practically unknown. In the Ũmánaq Fiord there are depths of more than 700 m., but it is perhaps doubtful whether the 500 m. curve continues between the Disko shoal and the coast shoal outside Svartenhuk Peninsula. The Upernivik Icefiord, which has a still greater depth (about 1000 m.), at any rate hardly continues as a submarine fiord with depths of more than 400 m.

In Melville Bay, the north-easterly part of Baffin Bay, the 1000 m. curve lies nearer the shore than along the whole of the distance north of Godthaab, but south of Smith Sound the latter, as well as the 500 m. curve, deflects in a south-westerly direction. West of the Carey Islands the maximum depth still exceeds 350 m., but from here it presumably decreases towards the north. From Kane Basin there are a couple of soundings recording depths of less than 200 m. in the middle of the basin, and the maximum

depths of the Kennedy and Robeson Channels scarcely exceed a couple of hundred metres; in the Robeson Channel the "Polaris" Expedition, it is true, registered a sounding of about 370 m., but Bessels himself says (1876, p. 9) that the sounding is uncertain.

Finally, as far as the north coast of Greenland is concerned, there are, as is well known, greater depths in the Arctic Sea than in the other waters round Greenland, but we possess no knowledge whatever of the configuration of the sea bottom towards the north coast of Greenland.

II. HYDROGRAPHY.

The primary cause of the ocean currents is the irregular distribution of temperature in our globe. In the equatorial regions the evaporation in the course of the year is several times greater than in the Polar regions and, through the wind systems arising out of the irregular distribution of temperature, part of the aqueous vapour is conveyed to the Polar regions, before it condenses and, in the shape of precipitation, comes back to the ocean, either falling over the Arctic Sea or over the adjacent countries, and from there, possibly after melting, is carried by the rivers to the Arctic Sea. In this manner the latter receives more water than it loses through evaporation, and the excess must consequently, by ocean currents, be carried away to the equatorial seas from where it came.

It is, however, not only through the air that the waters from the equatorial seas are carried to the Arctic Sea. The unequal temperature of the water within the two domains is apt to produce systems of currents attempting to equate the difference of temperature which produced them, thus bringing about an inflow of warm water to the Arctic Sea and an outflow of cold water from the same sea.

If the circulation of the water only took place through ocean currents, the volume of the warm water flowing in would be as great as the volume of the cold water flowing out. However, as mentioned above, the Arctic Sea receives more fresh water than it loses through evaporation, and so it appears that the volume of the cold water flowing out of the Arctic Sea must be greater than the volume of warm water flowing in. That this must be the case also appears from the fact that the inflowing water has a greater salinity than the outflowing; if the two volumes were equally great, the total quantity of salt in the Arctic Sea would go on increasing in the course of time.

The most important means of communication between the Arctic Sea and the equatorial seas are the waters between Greenland and Norway, the Bering Strait and the sounds between Greenland and the other North-American Islands which, in depth as well as in breadth, are insignificant in comparison with the Norwegian Sea (Greenland Sea). Consequently,

there is no doubt that by far the most important circulation between the Arctic Sea and the other seas is between the Atlantic and the Arctic Sea or, in other words, through the medium of the Norwegian Sea.

As is well known, a current runs from the Atlantic and northwards through the Norwegian Sea Sea along the coast of Norway. This comparatively warm current, known by the misleading and, consequently, not very appropriate name of the "Gulf Stream," after having undergone a considerable cooling in the Norwegian Sea, continues into the Arctic Sea, principally to the west of Spitzbergen. The masses of water given off by the Arctic Sea flow out of the latter between Spitzbergen and Greenland and keep to the west side of the basin.

This distribution of the two currents is the result of the deflection originating in the rotation of the earth, which force affects all moving bodies throughout the northern hemisphere, making them attempt to deflect to the right of their original direction of motion; thus the south-going current from the Arctic Sea, by the rotation of the earth, is forced towards the east coast of Greenland.

1. THE WATERS OFF EAST GREENLAND.

Along the east coast of Greenland we meet with the current proceeding from the Arctic Sea, and generally known by the name of the *East-Greenland Polar Current*. It carries considerable quantities of ice from the Arctic Sea into the North Atlantic, but perhaps it is not superfluous to draw attention to the fact that not all the ice occurring off East Greenland comes from the Polar Basin.

In the whole of the western part of the waters north of Iceland, i. e. the Greenland Sea, the winter temperature is so low and the hydrographical conditions of such a nature that an immense cover of ice forms during the winter, stretching for a couple of hundred miles from off the coast of Greenland. Helland-Hansen and Nansen (1909, p. 307) estimate the thickness of this cover of ice at about 1 m; according to measurings undertaken by the "Danmark" Expedition (Trolle 1913, p. 399) the ice formed in the fiords in 1907 was about 1¾ m., whereas in 1908 it was only about ¾ m.

Nearer the coast of Greenland there is, in particular off the northern part of the latter, a belt with considerably heavier masses of ice, which have been carried down here from the Arctic Sea, and which in winter are frozen up into a continuous ice field. The thickness is, according to Helland-Hansen and Nansen, 2—3 m. or more, and as contrasted with the ice formed in the Greenland Sea, this ice, which is several years old, is full of hummocks, the thickness of which may amount to 60—70 m. or more.

In spring the ice limit as a rule stretches from the north-western point of Spitzbergen down to Jan Mayen (about lat. 71° N., long. 8° W.) where it

deflects towards the south-west, in the direction of Northwest Iceland; sometimes the ice sends out an offshoot along the north coast and farther to the east coast of Iceland. From Northwest Iceland the ice limit as a rule rather deflects towards the west, across Denmark Strait, until south of Angmagssalik the ice continues in a comparatively narrow belt along the south-east coast of Greenland.

In spring when the solar warmth begins to melt off the ice and the spring gales set in, the year-old ice of the Greenland Sea breaks up and drifts southward, exposed to the radiation of the sun, through which it is gradually disintegrated. Later in the summer, as a rule in the month of July, the ice breaks up in the fiords and along the coast, where, besides the solar radiation, it is also exposed to melting in consequence of the fact that comparatively warm melting water pours across the ice from the snow and ice on land; thus a belt of open water forms along the coast, in which there are comparatively small quantities of drift ice, and often none at all. Also the Polar ice, several years old, which in winter lies as a solid mass off the east coast of Greenland, is partly broken up; openings nearly always form between the floes, often making a system of channels which permit of navigation through the ice.

The whole of the mass of ice which in winter is to be found in the Greenland Sea north of Iceland is presumably in a mainly southward motion, with the exception of the ice in the fiords and between the skerries along the coast, but there is no doubt that the velocity increases after the ice has broken up. It then recedes in a southerly and south-westerly direction and leaves the Greenland Sea through Denmark Strait.

As mentioned above, the belt of ice becomes narrower south of Angmagssalik, and there is hardly any doubt that this has a bearing upon the increase of the rapidity with which the ice moves; at the southern part of the east coast of Greenland the velocity may thus amount to more than a mile an hour, which fact, however, we will revert to in detail later on.

Seeing that the ice off the south part of the coast moves with such great velocity, it is not excluded that the year-old ice, the winter ice, may get away in the spring from the Greenland Sea and pass by Cape Farewell on to the west coast of Greenland, but if they are heavy masses of ice, they can undoubtedly, like the ice occurring later in the season, be traced to the older ice from the Arctic Sea.

The fact that the ice from the Arctic Sea is able to drift all the long distance to Southwest Greenland, without being quite dissolved, is greatly due to the peculiar conditions of temperature in the East Greenland Polar Current, the latter consisting of water-masses with a negative temperature. Only for a short period during the summer a temperature exceeding 0° occurs in the openings between the ice, but even then it is only a thin layer of water, rarely more than 10 m. in thickness, which is of a positive tem-

perature. Not until the ice is melted, does the warmth from the surface make itself felt at greater depths.

A water layer of this kind, with a negative temperature, arises everywhere in seas where ice forms, in consequence of the fact that sea water only freezes at temperatures below 0°. The freezing point, as is well known, depends upon the salinity of the water, but in these water masses it lies about—1.8°

The formation of ice in the deep seas, where there is a bottom layer with a temperature above the freezing point of sea water, is, however, dependent upon the occurrence of a surface layer with a lower salinity than the bottom water. Where this is not the case, as for instance, in the central part of the Norwegian Sea, east of Jan Mayen, the surface water, during the winter, will only be cooled when the temperature is nearly constant from surface to bottom (in reality increasing very slowly downwards) and a continued cooling will not cause the formation of ice, but only an extremely slow cooling process, extending through the whole of the huge water layer, because the surface water becomes heavier than the underlying layer and therefore sinks downwards and mixes with the latter. (Nansen 1906, p. 85 ff.).

In the Arctic Sea there will, on the other hand, be a surface layer of a lower salinity than the deeper water layers, in consequence of the fact that this sea does not, through evaporation from the surface, give off as much fresh water as it receives (mainly from the Siberian rivers). This surface layer can then be cooled to its freezing point, without growing as heavy as the under layer; consequently ice is formed, and as the greater part of the salt in the frozen water is absorbed in the layers below the ice, their salinity is increased in the course of the winter.

Thus a surface layer arises in the Arctic Sea with a temperature near the freezing point of the water (about—1.8°) and with a salinity which has increased to about 34 $^0/_{00}$. Seeing that this cold water layer, the thickness of which, according to the researches of Nansen (1902, p. 306), is about 200 m., is to be found extending over the Arctic Sea all the year round, and that the East Greenland Polar Current is a surface current proceeding from this basin, it will be understood that *the low temperature of the East Greenland Polar Current is due to the cooling of the Arctic Sea* in winter[1]).

An idea of the temperatures in the East Greenland Polar Current is obtained from the accompanying fig. 2, representing a vertical section through various research stations along the east coast of Greenland from lat. 78° N. to the south-east point of the country. Conditions in the longitud-

[1] Under the winter-ice of the Greenland Sea, or in other words on the east side of the Polar Current proper, a similar cold water layer naturally forms during the winter, but the thickness of this layer is considerably less, and by the heating in the course of the summer the negative temperature disappears.

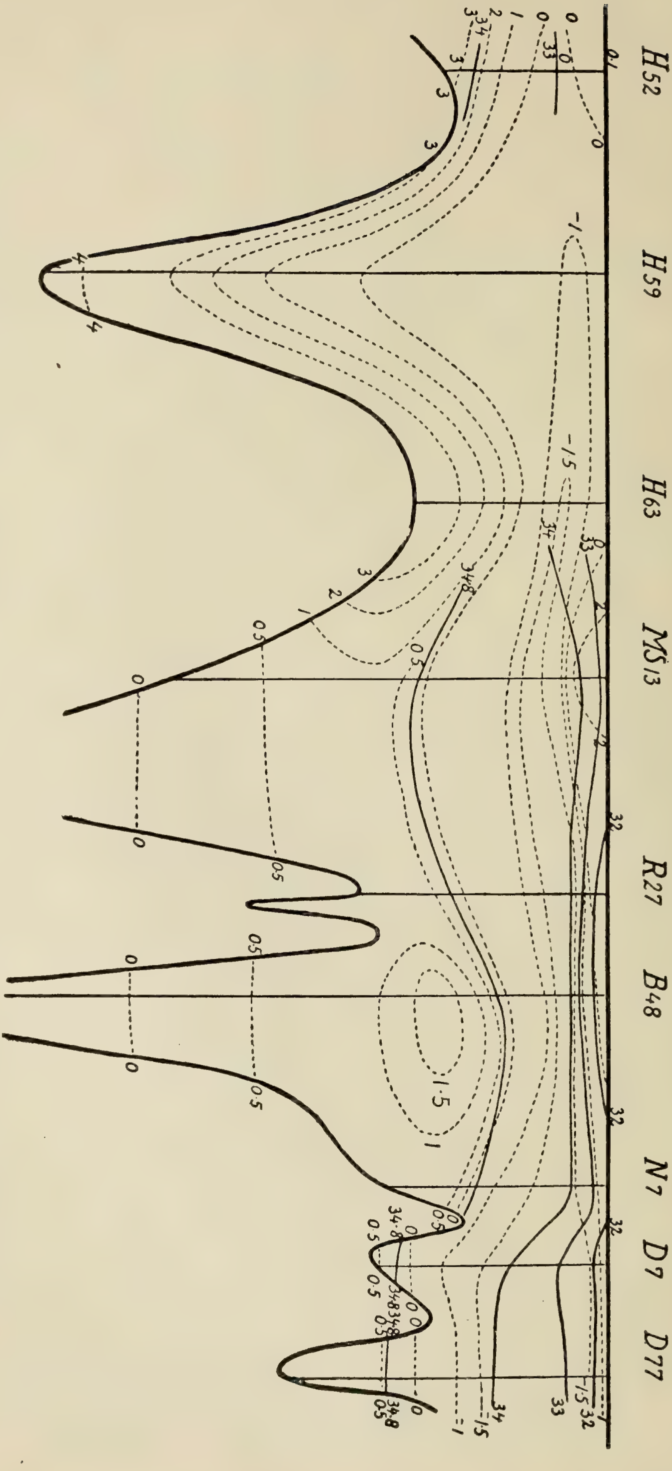

Fig. 2. Horizontal Scale: 1 mm = 15 km. Vertical Scale: 1 mm = 10 m. The dotted lines indicate the temperature, the unbroken lines the salinity.

inal direction of the current are, however, not so irregular as indicated by the figure. The reason why the isotherms curve so strongly is, in part, that the researches forming the basis of the section have been undertaken in six different years, but, still more, that they have been undertaken at various periods during the summer, and that some of the stations on the coast shoal lie close to land, whereas others are situated at a greater distance from the coast, "Belgica" St. 48 being even outside the 1000 m. curve.

In the northern part of the section, on the broad coast-shoal north of lat. 75° N., the thickness of the water layer with a negative temperature is nearly 250 m. and at St. 7 and 77 of the "Danmark" Expedition, investigated in 1906 and 1908 respectively, there is a water layer of nearly 150 m. the temperature of which is below $-1.5°$; the lowest temperature is registered in 125 m. at St. 77, *viz.* $-1.80°$. This value is only 0.05° above the freezing point of the water, and it is consequently to be supposed that at this depth no actual change has taken place since the winter; as the salinity at 125 m. is 33.86 $^0/_{00}$, it appears, as mentioned above, that the salinity of the cold water layer formed below the ice in the course of the winter approximates 34 $^0/_{00}$.

The surface temperature lies considerably above the freezing point of the water; at St. 77 of the "Danmark" Expedition it is even 0.69°, but already at 5 m. the value $-1.38°$ occurs. The high surface temperature is naturally due to the fact that the rays of the sun are absorbed in the upper water layer, but for stations near the coast there is another concurrent cause in the fact that comparatively warm melting water flows out from the land. As all the stations represented in the section are investigated from ships which must necessarily keep to open water, it will be understood that the surface temperature in the whole of the section is relatively high; if an ice floe drifts across the open water, the latter will give off heat for the melting of the ice, and thus be cooled to somewhere near its freezing point. So it also appears that in all the measurings undertaken from the ice by the "Danmark" Expedition there are, beneath the ice, temperatures not much above the freezing point of the water.

South of the large coast shoal off Northeast Greenland the thickness of the Polar Current seems to decrease, and at "Belgica" St. 48 off Davy Sound the thickness of the water layer with a negative temperature is even less than 150 m. When approaching Denmark Strait the thickness apparently again seems to increase; at "Michael Sars" St. 13 the lower 0° isotherm lies at about 250 m., but here where we are undoubtedly on the outskirts of the Polar Current, there is from the surface to a depth of more than 50 m, a positive temperature in a water layer, the origin of which is not exclusively Polar.

On the Iceland-Greenland Ridge, at Hamberg's St. 63 close to the coast of Greenland, north of Angmagssalik, there is still at a depth of 50 m. a

temperature as low as $-1.5°$, but the vertical thickness of the Polar Current proper with a negative temperature, is here not much more than 100 m. About lat. 63° N. where the coast shoal is very narrow, Hamberg at St. 59 recorded 0.2° at 400 m., which seems to show that the Polar Current in this place has increased very much in depth. Though this looks somewhat improbable, it is hardly quite safe to reject this supposition, which in the first place is supported by the low salinity value, i. e. 32.48 $^0/_{00}$ at 400 m., and secondly the breadth of the Polar Current, at the beginning of September, 1883, was very slight; thus it is possible that the observed contraction of the Polar Current is the very result of its having had an unusual extent in depth.

Towards the south point of Greenland the thickness of the cold water decreases; at Hamberg's St. 52 to the east of Cape Farewell its thickness hardly amounts to more than 50 m, and the lowest temperature registered was not much below 0°. We must, however, bear in mind that these researches were undertaken about September 1st, whereas the Polar Current, as will be shown later on, is much more pronounced in the spring.

It has been mentioned above that the salinity of the cold water layer beneath the ice was probably somewhere near 34 $^0/_{00}$ and fairly constant through the whole of its depth. Nevertheless, fig. 2 shows that the salinity of the surface is much lower, often even less than 30 $^0/_{00}$, and increases greatly in a downward direction from the surface. This is of course due to the fact that, by the melting of the ice, large quantities of fresh water arise during the summer and gradually mix with the upper layers. However, at the depths where the lowest temperature occurs the salinity during the summer, over the whole of the stretch north of Denmark Strait, is somewhere near 34 $^0/_{00}$. Below the temperature minimum the salinity also increases downwards, and at the lower 0° isotherm a salinity occurs which as a rule is somewhere round 34.70—34.80 $^0/_{00}$. Consequently, if the 0° isotherm is taken as the deeper limit of the Polar Current, the 34.8 $^0/_{00}$ isohaline will also approximately give the lower limit of the Polar Current in the Greenland Sea.

That the temperature of the East Greenland Polar Current, as shown in the figure, increases towards the south, is due to two different causes. The first of these causes is, as already suggested, the radiation of the sun and the facts connected herewith or, briefly, a heating from the surface. Gradually, with the springing up of openings between the ice floes, the surface water is heated, and the more scattered the ice becomes, the higher the surface temperature rises. The solar warmth is, however, comparatively quickly absorbed, and it is an extremely small fraction which reaches a depth of 25 m.

The descent of the heat is further counteracted by the decrease in the salinity at the surface, according as the ice melts, and the melting water mixes with the surface layer; thus, the latter becomes much lighter than

the deeper water layers, and there is consequently no tendency to the forming of vertical currents, which might conduct heat downwards. Vertical currents of this kind must, however, have been in operation, for we see that the heating from the surface extends to depths of 50 m. or more, and they undoubtedly act most strongly on the coast shoal; in places where the water runs over an uneven bottom and past islands and skerries, vertical motions arise, carrying the mixture of the waters down to the depths in question.

A contributory cause to the increase of temperature in the Polar Current in a southern direction is the fact *that the latter, in the whole of its course, rests upon an underlayer of water with a positive temperature.* In the deeper channels on the coast shoal north of lat. 75° N. we thus, in fig. 2, meet with a temperature of more than 0.5°, when the depth exceeds 300 m. The salinity of this comparatively warm water lies between 34.8 and 34.9 $^0/_{00}$, and as the salinity in the lower part of the water masses of the Polar current is about 34.8 $^0/_{00}$ it appears that the density of these masses is not much less than that of the warm under layer. Mixing is very apt to take place between the two water layers, the result of which is that the cold water is being heated at the same time as the warm under layer is being cooled. The farther the water masses of the Polar Current have moved towards the south, the longer they have been exposed to this heating from the under side, and the higher the temperature of the Polar Current has risen.

The existence of this comparatively warm under layer was first demonstrated in 1890—91 by Capt. Ryder, who at once gave the correct explanation of its origin, when stating (1895, p. 204): "In my opinion it is probable *that this warm current must originate in a continuation of the warm current along the west side of Spitzbergen.* I do not consider it improbable that the latter warm, salt current, after having passed along the coasts of Spitzbergen, by meeting the south-going cold Polar Current is deflected towards the west in the direction of the coast of Greenland, and then follows the cold current along the latter in a southerly direction."

Capt. Ryder suggests as a possibility that the warm under layer might have proceeded from the Davis Strait and Baffin Bay north of Greenland, as Moss and Nares were of opinion that they had found a warmer under current through Smith Sound and the Kennedy and Robeson channels. As will subsequently appear, there is no foundation for Moss' and Nares' supposition, whereas in the Arctic Sea there is a similar warm water layer, as below the East Greenland Polar Current, and at a later period Nansen suggests that part of the warm under layer may have proceeded from the Arctic Sea, together with the overlying cold water layer (1906, p. 76).

Even though this is not excluded, particularly in the case of the warm under layer occurring on the coast shoal nearest Greenland, the researches carried on by the "Belgica" Expedition (see Helland-Hansen and Ko-

foed 1909, pl. LXIV and LXV) leave no doubt of the fact that the main part of the warm under layer, as indicated by Ryder, proceeds from the Atlantic Current in the east side of the Norwegian Sea. Whereas part of its water masses, after undergoing cooling and admixture in the Greenland Sea, proceeds into the Polar basin, a presumably small part, west of Spitzbergen, deflects towards the west and south-west and, by the distribution of densities, is made to find its level as an intermediary layer between the East Greenland Polar Current and the cold bottom layer of the Greenland Sea.

Of the East Greenland Polar Current and the extent of the warm under layer away from the coast, an idea is obtained from fig. 3, drawn from

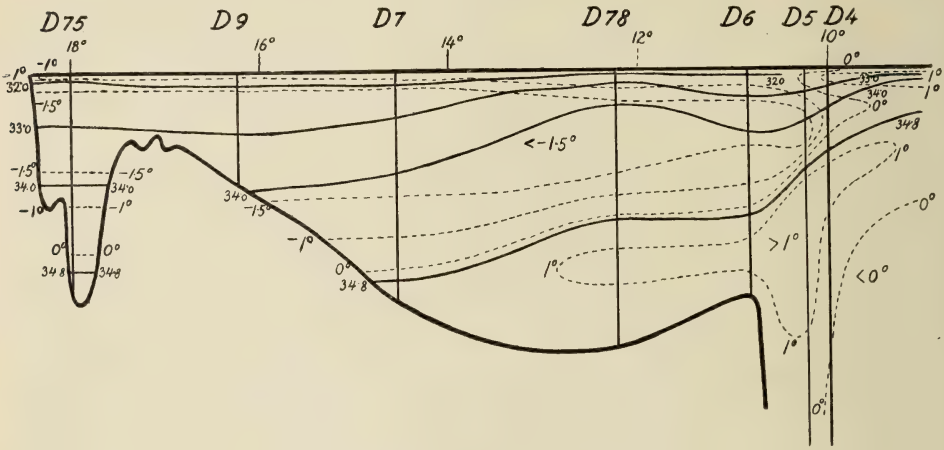

Fig. 3. Vertical Scale: 1 mm = 10 m.

Trolle's section I (1913, pl. XV). It appears that the warm intermediary layer has its highest temperature and, more especially, its greatest vertical thickness in the deeper water above the continental edge, whereas the temperature is somewhat lower above the coast shoal; across the continental edge there is a positive temperature down to depths of about 800 m. When in fig. 2 we found the highest temperature—about 1.5°—at "Belgica" St. 48, we consequently cannot conclude from this that the temperature of the warm under layer increases towards the south, but this is exclusively due to the fact that the latter station lies in the warmest water to be found outside the coast shoal.

From fig. 3 it appears that the Polar Current is chiefly bounded by the coast shoal, seeing that the — 1° and — 1.5° isotherms do not reach much beyond it. Further, it appears from Trolle's section I that the dense pack ice, or the ice from the Arctic Sea, only occurred across the coast shoal above the coldest water, whereas outside the coast shoal there was only loose packice. This turned out to be the case above the great coast-shoal

north of lat. 75° N., but when, on the strength of this, Trolle (1913, p. 365) drew the conclusion that this would be the case everywhere, and that a narrowing of the coast shoal likewise marked a contraction of the Polar Current, then he was very far from being correct, seeing that the Polar Current farther south spreads over deep water and throws off a branch towards the south-east.

The determinations of salinity in the warm under layer are not all equally reliable, which is partly due to the fact that a number of the samples of water were kept too long before they could be analysed. The best samples, however, show a maximum salinity of 34.9 to 35.0 $^0/_{00}$ in the warm under layer, in which salinity as well as temperature decreases towards the bottom water. The latter, as mentioned above, is the result of the winter cooling of the central part of the Norwegian Sea, where there is no surface layer of low salinity. Its salinity is about 34.9 $^0/_{00}$, and its temperature approximates —1.3° or somewhat higher than the minimum temperature of the East Greenland Polar Current. However, in consequense of its lower salinity, this current, the temperature of which is the lowest occurring in the Norwegian Sea, protects the warm, intermediary layer against cooling from the surface, and we may thus say that the latter owes its existence to the East Greenland Polar Current.

THE FIORDS OF EAST GREENLAND.

It appeared from fig. 2 that above the North-east Greenland coast shoal there was a negative temperature to depths of about 250 m. In the shallower parts of the shoal the bottom temperature will thus be negative as, e. g., above the "Belgica" Bank in lat. 78° N. and the shoal off Germania Land. Where the depth exceeds 250 m. it is, on the other hand, impossible to know in advance what is the bottom temperature. When there are depressions in the shoal, where the depth exceeds 300 m., and the depression is continued through the whole of the coast shoal as far as the deep basin, the warm water from the intermediary layer will have free circulation, and the latter will then spread along the bottom across the depression. Where there are isolated deep holes surrounded by depths of less than 200 m., these, on the other hand, will presumably be full of water with a negative temperature.

Similar conditions will undoubtedly hold good as far as the fiords are concerned. In fig. 4 the dotted curves indicate the temperature of Dove Bay, inside the Koldewey Island, as well as of Franz Joseph Fiord and Scoresby Sound, and for comparison has been added the temperature at „Danmark" St. LXXXIII towards the outskirts of the coast shoal, in about lat. 76° N. Whereas the temperature in the latter station has a pronounced maximum at 250—275 m. with values above 1°, the maximum in Dove

Bay and Scoresby Sound lies considerably deeper, in the latter even about 475 m., though in both cases the under layer has a positive temperature; in Scoresby Sound the temperature at Ryder's St. XXIV, however, again seems to decrease to about — 0.3° at the bottom, whereas a similar decrease of temperature does not occur at the other Ryder stations in Scoresby Sound, where the depths, however, on an average are somewhat smaller.

In Franz Joseph Fiord the temperature is below 0° down to the greatest depths; though, on the other hand, it increases rather considerably from 300 m. to about — 0.4° at depths exceeding 600 m. The negative temperature in this place is the reason why, as mentioned in the chapter on depths, we must suppose that this fiord is not continued as a submarine fiord through the coast shoal; in any case we must suppose that in some place or other, perhaps at the mouth of the fiord, there is a threshold, beyond which the warm under layer cannot penetrate. The temperature and salinity of the bottom water suggest that the depth of this threshold is about a couple of hundred metres, seeing that the bottom layer more especially seems to originate in the deepest water masses of the Polar Current.

The depth at the mouth of Davy Sound, which forms the southernmost entrance to the Franz Joseph system of fiords, is presumably about 500 m., but seeing that the warm water, which undoubtedly penetrates into the mouth of this sound cannot by this route reach the inner part of Franz Joseph Fiord, we are bound to suppose that somewhere in the Davy Sound there is a barrier with depths of less than 300 m.

A common feature of all the fiords is the cold upper layer, the temperature of which, as in the Polar Current off the coast, has a minimum, with temperatures round the freezing point of the water. This upper layer also originates in the Polar current and is only distinguished from the latter, in that it undergoes greater changes in the course of the year than is the case in the Polar Current off the coast. In summer, when the ice breaks up, considerable quantities of comparatively warm melting water are carried to the fiords from the land, and the temperature of the surface water of the fiords may therefore amount to some ten degrees. The density of the upper water layer is reduced through heating and particularly through the admixture of fresh water, and it consequently flows out of fiords and farther away from the coast, at the same time as it is carried southward by the Polar Current. Thus it contributes towards the formation of the ice-free belt of coast water, which in summer occurs along a great part of the east coast inside the belt of Polar ice.

In autumn, when the cooling commences, and ice floes are formed, the salinity of the surface layer nearest the coast, and more especially in the fiords, is comparatively low; this layer is gradually concentrated through the freezing, but the salinity remains lower than that of the East Greenland Polar Current, which may in part be concluded from the salinity of the

cold water (see the salinity curves in fig. 4) and in part also appears directly from the numerous measurings undertaken by the "Denmark" Expedition from the ice in the course of the winter and spring.

The summer outflow of the surface layer of the fiords favours the renewal of the under layer of the latter. The fresh water, before flowing out, is mixed with the sea water, and this carries salt out of the fiord; this loss is partly

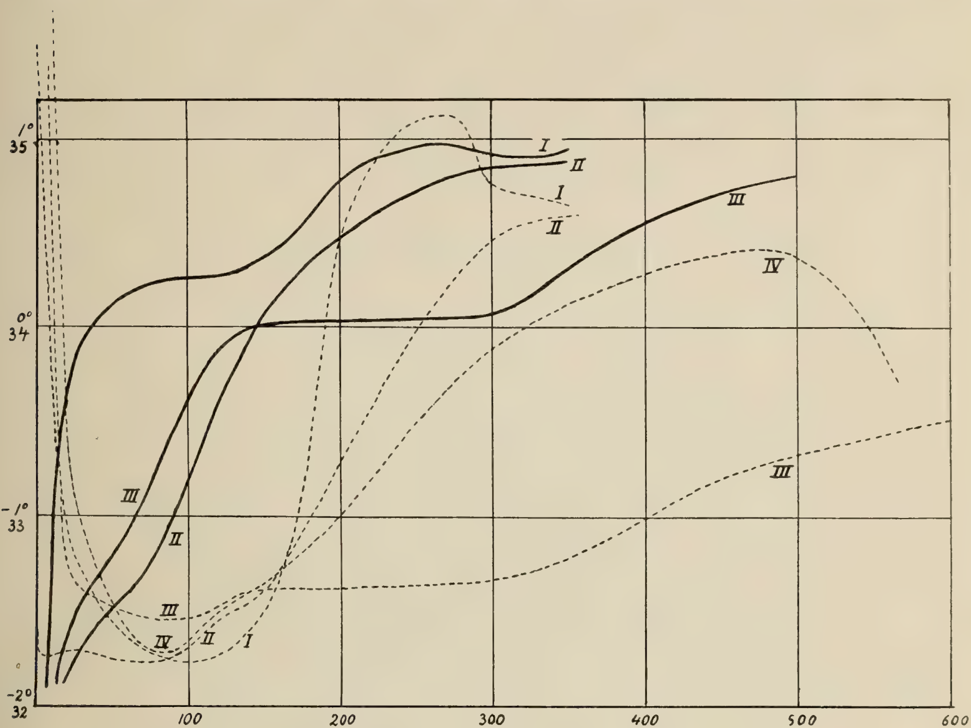

Fig. 4. The Curve marked I represents the "Danmark" St. 78 (75° 52′ N, 12° 15′ W), II St. 58 in Dove Bay, III St. 13 Nathorst's in Franz Joseph Fiord, IV St. 24 Ryder's in Scoresby Sound.

compensated by an inflow into the bottom layer, in which there is thus a velocity component directed towards land. The warm under layer occurring in the fiords, where the depth of the coast shoal is sufficiently great to allow of its penetrating into it, thus owes its existence to a compensation current, partly brought about by the surface outflow from the fiords.

From the outlines given above it appears that in the fiords, and more particularly in their upper layers, considerable variations take place in the course of the year. Ryder and Trolle, who spent several winters in Greenland, have made valuable contributions to the determinations of these variations, into the details of which we will not enter in this place.

2. THE WATERS OFF SOUTH GREENLAND.

What has been stated in the preceding applies to the part of East Greenland situated to the north of Denmark Strait. When approaching the latter the East Greenland Polar Current divides, so that part of its water masses deflect towards the east and keep to the north of Iceland and the Faroe-Iceland Ridge, where it is called the East Iceland Polar Current. The latter is most frequently free from ice, whereas the Polar ice, with the remaining part of the East Greenland Polar Current, is carried through Denmark Strait, and as has already been mentioned, the breadth of the Polar Current to the south of Denmark Strait is much less than north of the latter, which fact may thus be explained by its yielding part of its water masses to the East Iceland Polar Current.

The ridge between Iceland and Greenland, consequently, does not form any unsurmountable obstacle to the East Greenland Polar Current, but, on the other hand, there is reason to suppose that the Polar Current in this place meets with greater resistance, the result of which is that part of its water masses north of Iceland deflect towards the east. As to the warm under layer below the Polar Current, the effect of the ridge is far more thorough, and it is presumably only a very small part of the warm intermediary layer which makes its way across the Iceland-Greenland Ridge. Therefore it deflects towards the east, and north of the Faroe-Iceland Ridge its existence may still be proved as an intermediary water layer with a positive temperature and a salinity of nearly 34.9 $^0/_{00}$[1].

It was already demonstrated by Admiral Irminger that the warm waters of the Atlantic threw off a branch along the west coast of Iceland, and subsequent investigations undertaken from the cruiser "Fylla" and later on by the "Ingolf" Expedition elucidated the hydrographical conditions of Denmark Strait. Basing his researches on the latter investigations Knudsen (1898, p. 112) showed that the Irminger Current, when meeting the East Greenland Polar Current off North-west Iceland, divides into two branches, one of which deflects west towards the coast of Greenland, running along the latter in a southern direction and forming the under layer of the Polar Current.

Thus the under layer of the East Greenland Polar Current, over the whole of its extent, consists of comparatively warm water, though, on the other hand, it appears that the warm under layer varies somewhat in character; south of the ridge between Iceland and Greenland it consists of water from the Irminger Current, and the temperature of the latter is hardly less than 4° and may, as will be shown later on, even amount to more

[1] The latter water layer is in part also being renewed through other sources, *viz.* through the branch of the Irminger Current, running to the north of Iceland, which fact has been mentioned in a previous work by the present author (1905, p. 21).

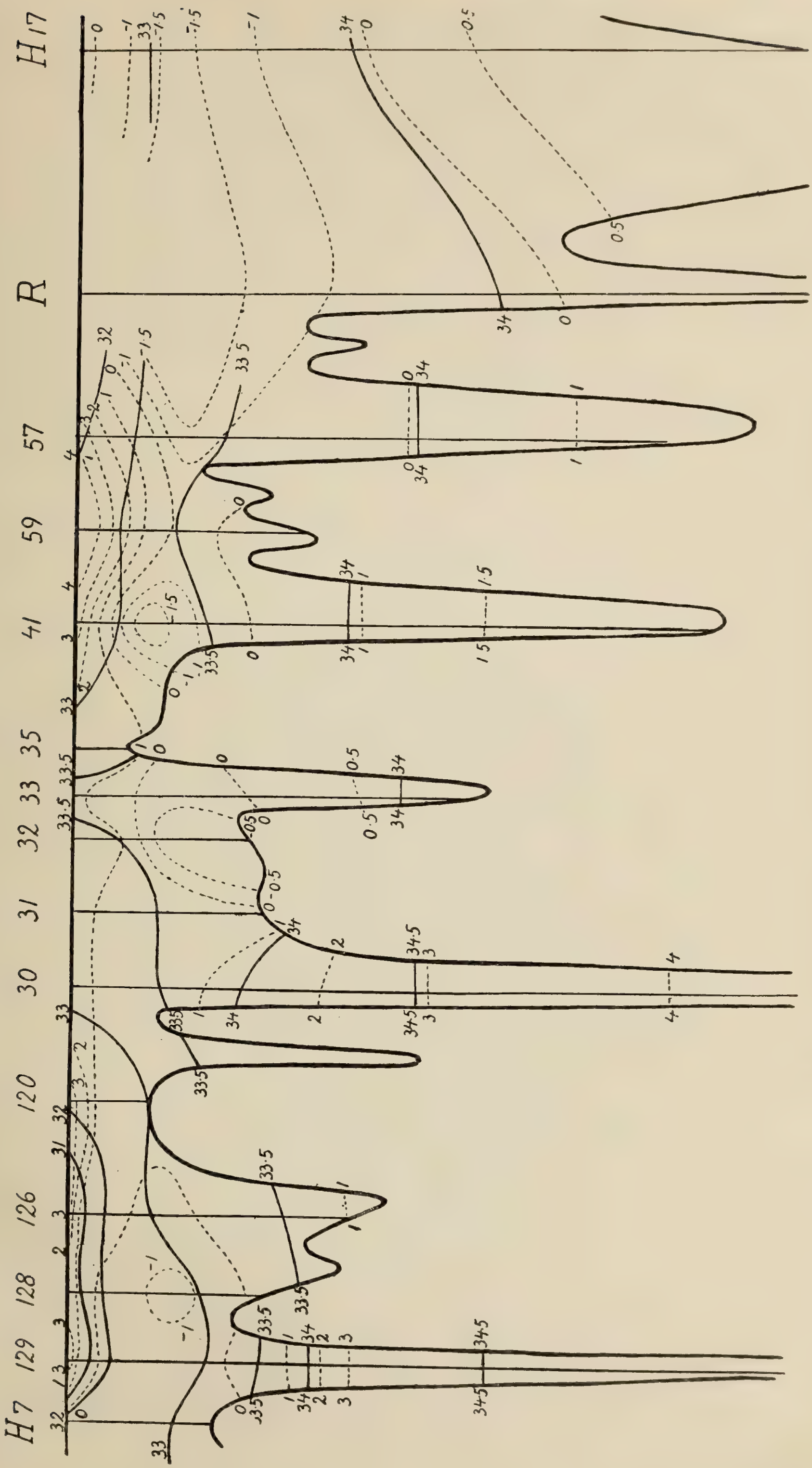

Fig. 5. Horizontal Scale: 1 mm = 15 km. Vertical Scale: 1 mm = 10 m.

than 6°; north of this ridge the temperature of the under layer hardly exceeds 1.5°, and this is due to the Spitzbergen Current.

When having reached the south point of Greenland the East Greenland Polar Current does not continue in a southerly direction, but deflects towards west and north-west, along the south-west coast, the course of which is primarily to be looked for in the deflecting influence of the rotation of the earth. The same holds good of the warm under layer below the Polar Current, and there is consequently no material difference between the hydrographical conditions in the seas east and west of South Greenland, beyond the necessary consequence of the heating of the water masses of the Polar Current and the melting of the ice along the distance travelled.

It is also a well-known fact that off the southern part of the west coast of Greenland there are in spring and during the early part of summer considerable quantities of ice ("Storis"), and below the ice there is a typical continuation of the East Greenland Polar Current, which appears from the accompanying fig. 5, representing a vertical section through part of the stations of the "Tjalfe" Expedition from Julianehaab as far as north of Disko Island. In this section are further included "Hamberg's" St. 7 off Nanortalik and St. 17 in the Melville Bay, as well as the measurings of Ryder in the Upernivik Icefiord. With the exception of the measurings of Ryder, which were undertaken in January, 1887, all the observations are carried out in the period June 16th—August 9th.

In the southern part of the section the surface temperature, as off East Greenland, greatly varies in consequence of the ice conditions, but at a small distance from the surface we find water with a negative temperature, which on the coast shoal north of Nunarssuit extends downwards to 125—150 m. In the coast shoal off Fiskernæsset (St. 120) the temperature is everywhere positive (at the bottom only slightly exceeding 0°); this, however, does not mean that negative temperatures do not occur so far north, for whereas the coldest water off the southernmost part of the west coast of Greenland is to be found nearest the shore across the coast banks, this is no longer the case when reaching Godthaab. From fig. 6, which is based upon the "Tjalfe" researches from Godthaab towards west-south-west in June, 1908, it appears that the lowest temperature (less than —0.5°) is registered at a distance of about 120 miles from the shore, and there is a negative temperature as far as 200 miles from the shore, whereas the temperature on Fylla Bank close inland is a little more than 0°.

As the breadth of the Polar Current off South Greenland hardly amounts to a couple of degrees of latitude—Wandel (1893, p. 88) even estimates its breadth south of Cape Farewell at 20—30 miles only—the considerable increase in breadth off Godthaab, in connection with the distribution of temperature, shows *that part of the water masses of the Polar Current are here on the point of leaving the coast;* then they pass towards the west and unite

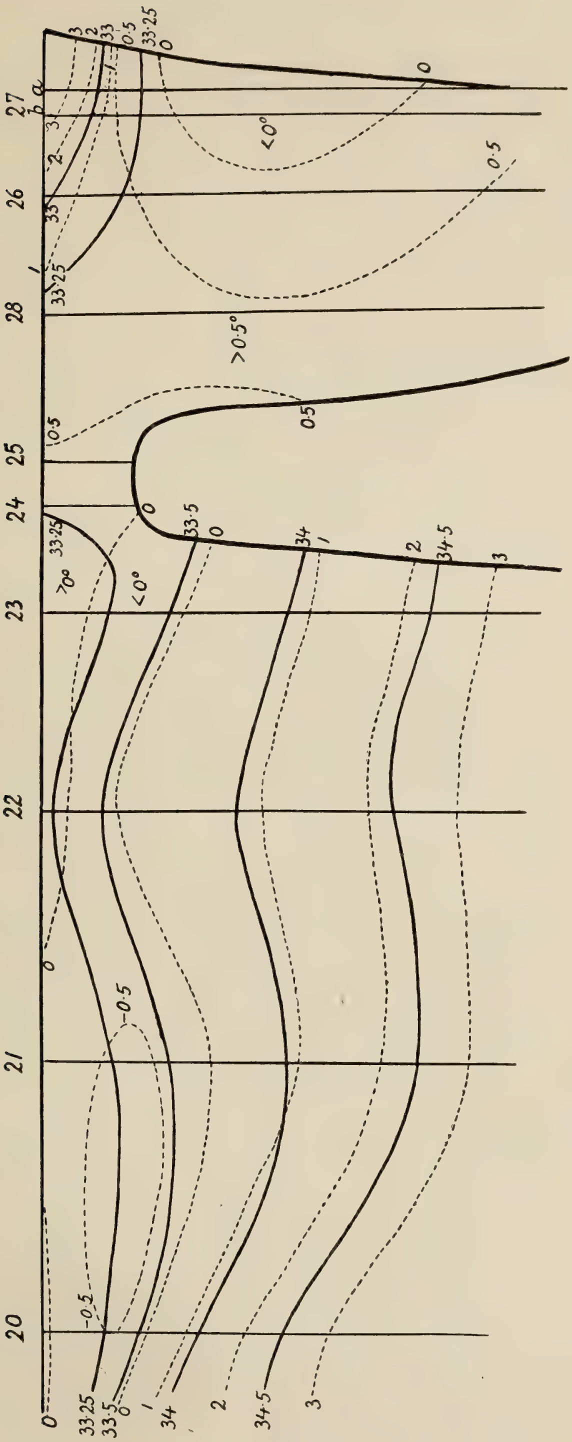

Fig. 6. Horizontal Scale: 1 mm = 2 km. Vertical Scale: 1 mm = 5 m.

with the cold current in the west side of Davis Strait, passing from Baffin Bay in a southerly direction (the Labrador Current).

However, as shown in figs. 5 and 6, the temperature of the Polar Current increases towards the north, and we have already mentioned how this comes about. Here the heating from the surface is undoubtedly by far the most important factor, because the ice as a rule has melted away before it reaches Godthaab, and the amount of heat received through the radiation of the sun may then be accumulated in the water without being consumed for the melting of ice. Also, off the southernmost part of the coast

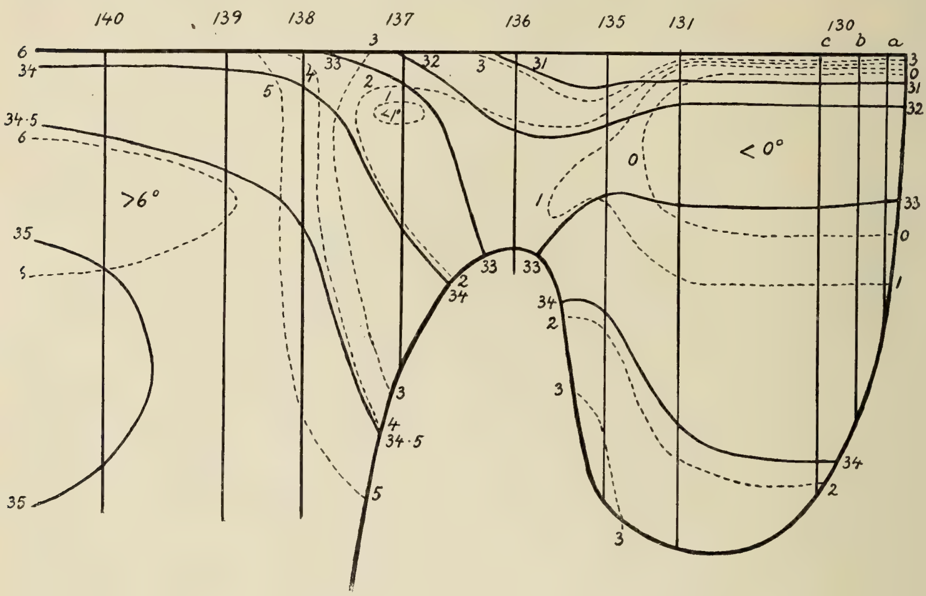

Fig. 7. Horizontal Scale: 1 mm = 2 km. Vertical Scale: 1 mm = 5 m.

the Polar Current is heated considerably in the course of the summer, as we have already seen from fig. 5, and, as appears still more clearly, from fig. 7, showing a series of investigations carried on by the "Tjalfe" in September, 1909, from Julianehaab in a southerly direction.

From fig. 7 it appears that at St. 136, above the most shallow part of the coast shoal and at all depths, there are temperatures exceeding 1°, and at St. 137, above the continental edge, only an extremely small part of the section registers temperatures slightly below 1°. In September, 1908, we found still higher temperatures on the coast shoal off Fiskernæsset, and if we want to keep to the above definition of the Polar Current, i. e. as a current consisting of water masses with a negative temperature, we must thus say *that in the autumn the East Greenland Polar Current has disappeared entirely along the whole of the south-west coast of Greenland*, but still there are, above the coast shoal, water masses of a comparatively low temperature

and salinity, which water masses are thus characterized as a continuation of the East Greenland Polar Current.

As appears from figs. 5 and 6, there is along the whole of Southwest Greenland outside the coast shoal and in the deep incisions of the latter below the Polar Current, a warm under layer, the temperature of which in spring is about 4°. Through influx from Denmark Strait the temperature of the under layer increases in the course of the summer, and in fig. 7 we find, at a comparatively short distance from the coast, water masses with a temperature exceeding 6°; off Fiskernæsset there was likewise in September, 1908, a temperature of more than 6°, about 100 m. below the surface.

Thus, the temperature, not only in the continuation of the Polar Current, but also in the under layer, increases during the summer, just as the colder water layer above the coast shoal decreases in thickness as well as in breadth; also, while the temperature of the bottom water on the coast shoal is below 0° in spring, it increases rather considerably in summer, and we have every reason to suppose that the warm under layer with a temperature of about 6° in the autumn extends beyond several of the coast banks, which fact is undoubtedly of great importance to the amount of fish on the latter.

The coast bank off Sukkertoppen—Little Hellefiske Bank—also in spring registers a negative temperature; in June, 1908, there was about −1° at the bottom of the northern part of the bank, i. e. "Tjalfe's" St. 32. From the comparatively high and rather constant salinity we must, however, conclude that the cold water occurring there is formed locally through cooling in winter, and does not originate in the East Greenland Polar Current. Off the northern part of the west coast of Greenland an intensive cooling takes place in winter, and solid ice forms, generally extending as far as somewhat south of Holsteinsborg and often as far as Sukkertoppen; whether Little Hellefiske Bank is or is not covered with ice, a water layer with a low temperature and a rather constant salinity will, at any rate, arise on the shallow bank.

The winter ice, however, if occurring at all in this place, breaks up early (in March or April) and moves away from the coast, and the occurrence of ice masses from the East Greenland Polar Current is very rare. The water is heated from the surface, so that even in the early part of the summer we find higher temperatures than farther south, where the Polar Current makes its influence felt.

On Great Hellefiske Bank, off Holsteinsborg, a very cold water layer undoubtedly forms in winter beneath the ice. In this place the latter breaks up in the early spring and moves away from the shore, and on the shallow bank, which in many places only has depths of about 50 m., the heating from the surface thus also makes itself felt in the early summer. At the beginning of July we found rather warm water on the southern part of the bank, and in 1909, when the "Tjalfe" Expedition, as early as the month

of May, undertook investigations in this place, there was a positive temperature on the southern part of the bank.

In the investigations carried on by the "Tjalfe" during the summer of 1908 we also find direct proof that the water on Great Hellefiske Bank is considerably heated in the course of the summer. Whereas at St. 35, included in the section of fig. 5, we found on July 3rd a temperature of about 1.2° at all depths, we registered on August 23rd, in the same year, a few miles farther north a bottom temperature of about 4° and a surface temperature of about 5°, which values are considerably higher than those found during the following days on the coast banks farther south. The heating also makes itself felt at a greater distance from the shore; towards the north-west part of the bank we found, in the latter half of August, 1908, at a depth of 80 m. a temperature of 2.35°, and this in a place where, judging by the researches carried on during the early part of July, the temperature must be supposed to have been less than 0°.

We thus arrive at the result that *in summer the temperature of the water on Great Hellefiske Bank is far higher than on the more southerly coast banks*, which may seem strange, seeing that the former in winter is covered with ice, whereas the greater part of the southerly coast banks are free of ice during the winter, and only towards the end of the season or during the spring receives a supply of drift ice from the East Greenland Polar Current. The fact that Great Hellefiske Bank is the coast bank which in summer registers the warmest bottom water, undoubtedly explains many conditions connected with the fauna, and is presumably the reason why the halibut, which during the spring live in the warm water on the continental edge, in summer move up on the bank and towards the shore in the neighbourhood of Holsteinsborg.

In the autumn when the cooling from the surface begins, the thin water layer above Great Hellefiske Bank cools comparatively quickly, and as early as December the sea may again be frozen over. As already suggested, there is reason to suppose that the temperature on the most southerly coast banks keeps on rising in the course of the autumn, owing to the influx from the intermediary water of the Atlantic. We then see that the temperature of the water above Great and Little Hellefiske Bank fluctuates, exclusively as the result of the transport of heat through the air, and with a comparatively short delay follows the temperature of the air, whereas the temperature on the southernmost banks is greatly delayed as compared with the temperature of the air, which difference is due to the effect of the East Greenland Polar Current.

We have already mentioned that the maximum temperature of the warm intermediate layer along South-west Greenland increases from about 4° in the spring to more than 6° in the autumn (fig. 7). This, however, only

takes place in a somewhat limited belt along the coast; whereas in September, 1909, we found the maximum temperature of 6.24° in 100 m. at St. 140 about 40 miles south-west of Nanortalik, only 3.3° was registered in 100 m. at lat. 58° N. 140 miles south-east of Cape Farewell, and in September, 1908, 3.5° in 100 m. 110 miles south of Cape Farewell. This shows that the intermediate current, which in the course of the summer carries warmer water masses to South-west Greenland south of Cape Farewell, does not exceed 100 miles in breadth, and that in spite of its intermediate position it once more bears the character of a coast current, the warmest water masses of which occur above the continental shelf, though the renewal in the course of the summer, by means of warmer water masses, makes itself felt at depths of more than 1000 m.

Off the east coast of Greenland the East Greenland Polar Current, as already demonstrated, protects the intermediary underlying layers, and the same—though in a somewhat less pronounced degree—holds good of the south and south-west coast, which, *inter alia*, appears from the measurings of temperature carried out during the spring in a southerly and south-westerly direction from Nunarssuit. Of the latter the following extracts are given:

Depth in metres	Distance from the shore in miles			
	35	90	125	180
100	4.01°	3.7°	3.11°	2.93°
200	4.04°	4.0°	3.12°	2.96°
400	4.35°	4.01°	3.15°	2.95°
700		3.41°	3.12°	2.95°
1000		3.10°	3.05°	2.93°

From this we may conclude that all the year round there is a higher temperature in the intermediary water layer near the coast than at a greater distance from the latter, and the cause of this must partly be looked for in the fact that at the greatest distance from the coast there is no surface layer of a low salinity. In this place the temperature between the surface and 2000 m. only varied between 2.85° and 2.96°, and the variation of salinity with the depth was also so slight that the whole of the water column almost attained an indifferent equilibrium.

There is hardly any reason to doubt that the salinity at a somewhat greater distance from the shore is still more uniform and the temperature somewhat lower, while the vertical movements arising out of the cooling of the surface in winter extends all the way down to the bottom. *In the waters south of Greenland, between the Greenland Polar Current and the Labrador Current, the greater part of the bottom water of the North Atlantic is then evidently formed*, and from this area it spreads over the whole of the North Atlantic,

where at the greatest depths there is a salinity of very nearly 34.9 ‰ and a temperature of about 2.5°.

Off the east coast of Greenland, north of the Denmark Strait threshold there were, as already mentioned, three water layers of different origin, *viz.* a cold upper layer, a comparatively warm intermediate layer and the cold bottom layer. South of the North Atlantic Ridge there are, on the other hand, at most two, *viz.* the cold Polar Current near the coast and below it a warm Atlantic layer, which evenly and imperceptibly passes into the bottom water of the Atlantic, so that the temperature, even at depths of 2,000—3,000 m., is not much lower than 3°[1]. Off the west coast of Greenland the low temperature further disappears in the course of summer, and the continuation of the Polar Current assumes the character of a coast current with a low salinity (see the isohalines across the coast shoal in fig. 7), whereas the temperature in the late autumn is not much below that of the Atlantic water outside the coast current.

THE FIORDS OF SOUTHWEST GREENLAND.

In the preceding an account has been rendered of the two different water layers—different as regards origin as well as regards hydrographical conditions—which at any rate during the summer prevail off the southwest coast of Greenland, and it is clear that hydrographical conditions in the fiords of the west coast, as in those of the east coast, are dependent upon the depths of the fiords.

The depth of a fiord, however, is an insufficient basis for conclusions as to the hydrographical conditions; in the case of the deeper fiords the latter are greatly dependent upon whether, through submarine depressions with depths as great as those occurring in the fiords, they are connected with the deep waters off the coast shoal, or whether the coast shoal in or outside the mouths of the fiords form thresholds with smaller depths than those of the fiords. As a rule the latter is the case, and then the depth of the threshold determines the hydrographical conditions in the deep of the fiord, which is the explanation of the greatly varying temperatures in fiords of the same depth.

Off the south part of West Greenland, where in spring the Polar Current is strongly pronounced, the water masses of the latter extend into the fiords forming their upper layer. The Polar ice, however, as a rule, does not extend very far into the fiords, and where there is no great supply of fresh

[1] In Denmark Strait I have, however, demonstrated certain irregular features of the bottom temperature on the south side of the ridge (1905, p. 16), but this is undoubtedly only a purely local phenomenon. Similar conditions are perhaps to be found in Davis Strait, as seems to be suggested by some of the older measurings of temperature, which yielded comparatively low values of the bottom temperature.

water and consequently no strong, outgoing low salinity current, the heating from the surface will make itself felt at an early period. Furthermore, it is clear that the very form of the fiord plays a great part in the movements and changes arising therefrom in the upper water layer.

At *Amitsuarssuk* (long. 44° 40′ W.) Hamberg (1884, p. 40) at the mouth of the fiord found a depth of 75 m., and at the end of August the temperature all over the fiord exceeded 0° down to this depth. In the interior of the fiord at 150 m. the temperature, on the other hand, was —0.6°, the salinity being about 33.4 $^0/_{00}$, which shows that the water from the Polar Current is still left in the deeper part of the fiord, and there is reason to suppose that the temperature in this place is negative all the year round, as the threshold at the mouth of the fiord prevents the bottom water from pouring out.

At *Tasermiut* a number of researches were undertaken by Moltke (1896, p. 110), partly in May and partly in August, 1894. At the latter period positive temperatures were only found down to a little more than 20 m. and then there was a water layer a couple of hundred metres in thickness and with a more or less constant temperature from —0.6° to —0.8°. The entire water layer in the fiord thus consists of water from the Polar Current, and there is no doubt that the low temperature is maintained all the year round in the deeper part of the fiord, which presumably only has a small depth outside its mouth.

From *the sound east of Sermersôq* (the mouth of *Sermilik*) we have researches undertaken by Moltke at the end of May, 1894, and by "Tjalfe" at the beginning of September, 1909. Moltke (1896, p. 112) found typical Polar water with temperatures between —0.7° and —1.0°, and only above 10 m. was there a positive temperature. At "Tjalfe" St. 134 there was a positive temperature, at least as deep down as 150 m., whereas in the bottom water it was less than 0°; at the bottom (340 m.) there was —0.37° and 33.3$^0/_{00}$, or in other words water from the East Greenland Polar Current. It is a striking fact that the heating extended as deep down as about 200 m.; in the preceding (fig. 7) we have, however, seen that there was at least as high a temperature in the coast current, and in the narrow sound mentioned here there will presumably be strong tidal currents which gradually carry along the deeper water masses; on the other hand, it is hardly probable that the temperature becomes positive at the greatest depths.

At *Agdluitsoq* the present writer undertook researches from "Tjalfe" (St. 133, slightly inside "Sydprøven") down to about 400 m. The temperature at this period everywhere exceeded 0°, though at 100 m. there was a minimum with only 0.07°. In the fiord there was a bottom layer with a vertical thickness of at least 200 m. and a temperature and salinity nearly constant, about 0.6° and 33.8 $^0/_{00}$ respectively, which shows that the coast shoal forms a threshold off the mouth of the fiord, into which the warm inter-

mediate layer cannot penetrate undiluted, seeing that the bottom water must be a composition of the former and the water masses of the Polar Current which, as shown by the constant temperature and salinity, after having passed the threshold at the mouth of the fiord sinks down to its deepest parts.

Julianehaab Fiord was investigated, first by Hamberg in 1883 and later on by "Tjalfe" in 1909. The accompanying fig. 8 represents the distribution of temperature and salinity at Hamberg's St. 9 (June 21st), "Tjalfe" St. 132 (August 4th) and St. 135 (September 15th). In June the temperature at

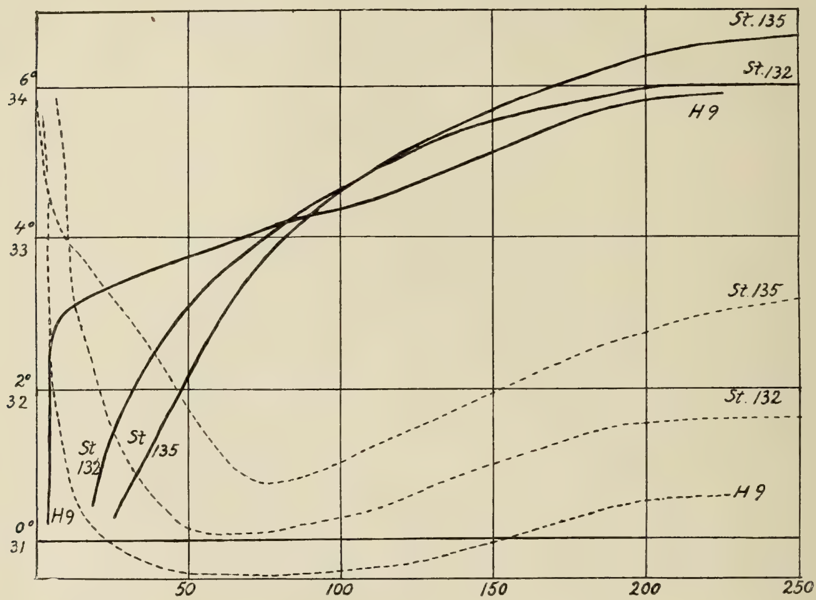

Fig. 8.

the surface exceeded 9°, but it was negative from about 20 to 150 m. with a minimum of —0.5° about 75 m.; in the bottom layer the temperature exceeded 0° and increased to 0.6° at the bottom (225 m.). At the beginning of August, 1909, the surface temperature is only 7°, but otherwise it is at all depths higher than in the month of June; the lowest value, 0.0° occurs between 50 and 60 m., where the difference of temperature is least, while at 10—20 m. it amounts to a couple of degrees, and in the bottom layer it is about 1° higher than in June, 1883. At the middle of September, when researches are again carried on in the same locality, the surface temperature is only 6.1°, but at all depths greater than 10 m. it has increased considerably; at about 75 m. where there is still a pronounced minimum, the increase is smallest (0.6°—0.7°), but it grows more rapidly throughout the depth of the bottom layer, and at the bottom, where the temperature is 3.28, the increase exceeds 1.6°.

In this place the change of temperature is so great that it cannot be explained by a heating from the surface only, which for that matter also appears from the fact that the salinity has changed rather considerably within the same period. Here it is thus a real renewal, through an outside influx, of the whole water layer in the course of the summer, and as the salinity of the under layer increases with the temperature, this layer must be renewed from the warm intermediate water outside the coast shoal. In the upper layer, on the other hand, the salinity decreases, at the same time as the temperature increases, and this layer must consequently be renewed from the remains of the Polar Current, *viz.* the low salinity coast current, which has been heated in the course of the summer. It will appear that the variations in the bottom water are great, and as Hamberg found a value as low as 0.6°, it is not excluded that the temperature at the bottom may approach 0°, so that, in the course of the year, one may meet all values from 4° and down to about 0°. At about 75—100 m. the variations in temperature as well as in salinity are smallest.

Farther up the fiords situated inside Julianehaab, *viz. Skovfiord* and *Tunugdliarfik*, there was at the beginning of August, 1909, an upper layer about 100 m. in thickness and with a temperature about —0.3°; at the surface, where the temperature was about 8°, there was only a thin layer which had been heated during the summer. This is due to the fact that the rivers carry great quantities of fresh water to the interiors of these fiords; in Tunugdliarfik (St. 130, see fig. 7) the salinity at the surface was only 10.5 $^0/_{00}$, in Skovfiord (St. 131) 31 $^0/_{00}$, and this fresh surface water, which absorbs the greater part of the rays of the sun, pours out of the fiords without mixing with the underlying cold water, thus causing no heating of the latter. There is, however, reason to suppose that the negative autumn temperature, even if it does not disappear altogether, rises considerably in consequence of the fact that the cold upper layer has been partly displaced by the inflowing warmer water, in the same manner as off Julianehaab.

In both of these fiords the temperature of the bottom water exceeded 2° and the salinity 34 $^0/_{00}$, or a little more than off Julianehaab at the same time of the year. On the other hand, Garde (1896, p. 58) at a somewhat lesser depth in Skovfiord (284 m.) found —0.2° as bottom temperature and negative temperatures at all depths below 30 m., which seems to show that the bottom temperature of these fiords undergoes rather considerable changes.

Bredefiord (Ikerssuaq) has been subjected to repeated investigations, *viz.* by Garde in 1893, by Moltke in 1894 and by the "Tjalfe" Expedition in 1909. The St. 129 of the latter, near the mouth of the fiord, is included in fig. 5 and likewise in fig. 9, from which it appears that there is a water layer of about 100 m. in thickness with a temperature below 0°, which water layer, as in the above-mentioned fiords, originates in the Polar Current.

At 200 m. the temperature, however, exceeds 3° and keeps between 3° and 4° down to the bottom (about 700 m.) with a maximum of 3.77° in about 500 m. The salinity, as also the temperature, is higher than in all the fiords formerly mentioned and in the bottom water reaches the value of 34.65 $^0/_{00}$. Practically the same results were obtained through the earlier investigations, though Garde (1896, p. 58) records a negative temperature in about 200 m., and Moltke (1896, p. 118) in about 175 m.; Moltke also observed that the thickness of the cold water layer decreased farther up the

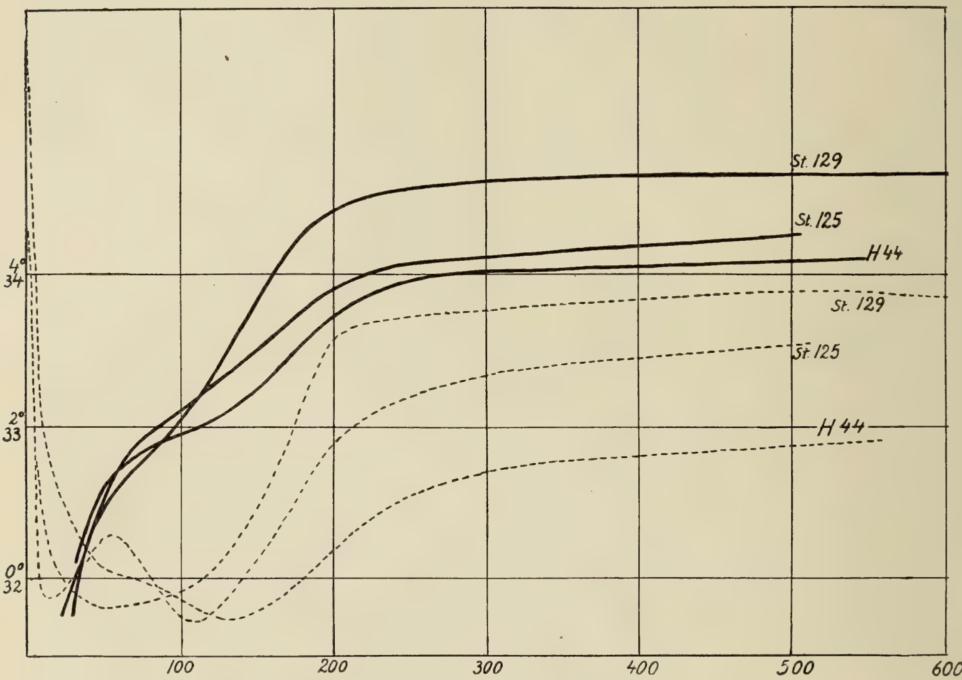

Fig. 9.

fiord, where towards the glacier, at the head of the Sermilik branch, he found 0° at 113 m.

The fact that the under layer in Bredefiord is warmer and of a higher salinity, being in other words more strongly Atlantic in character than in the other fiords of the Julianehaab District, might point in the direction of this fiord having a greater depth at the outlet than the other fiords; this, however, can hardly be considered a certainty, as it is possible that the warm intermediate water layer running up the bay to the inside of the Nunarssuit shoal, may in this place be pressed up to a higher level, and therefore more easily finds its way into Bredefiord than into the fiords farther south.

At *Qáqaligaitsiaq*, north-west of Bredefiord (inside Nunarssuit) where the depth amounts to a little more than 200 m., Garde (1896, p. 57) in July, 1893, only found Polar water with an almost constant temperature of

about $-0.2°$. At the very head of this fiord, the *Sermitsialik* Icefiord, Bloch (1893, p. 155) partly found bottom water with a negative temperature, partly a value of 5.2° in 132 m., which value must necessarily be incorrect.

Arsuk Fiord, in August, 1883, was subjected to a thorough investigation by Hamberg, who on the strength of his measurings makes statements which may be applied to a great number of West Greenland fiords (1884 p. 44 ff.). Fig. 9 represents the results of his measurings in the deepest regions of the fiord off Ivigtût, and it appears from the figure that here, as in the fiords formerly mentioned, there is a considerable upper layer of Polar water. The latter extends somewhat deeper down in the outer than in the inner part of the fiord, and below it temperatures above 0° occur everywhere; at "Hamberg's" St. 44 there is thus a huge, comparatively warm under layer, the bottom temperature of which, at 560 m., amounts to 1.8°; the salinity of this layer is fairly constant, slightly exceeding 34 $^0/_{00}$.

In *Kvanefiord* the "Tjalfe" Expedition took a series of measurings at the mouth of the fiord, and another series towards the glacier in the interior of the fiord; the latter (St. 125) are included in fig. 9, which shows that in this fiord a huge warm under layer occurs, the temperature of which, at a depth of 500 m., even rises to above 3°; at the same time the salinity is somewhat higher than in Arsuk Fiord, seeing that at 500 m. we found 34.25$^0/_{00}$ or rather pronounced Atlantic water. The upper layer consists of water from the Polar Current, but in Kvanefiord peculiar conditions occur, *viz.* at about 50 m. a secondary temperature maximum of a little more than ½°; this maximum, also observed at the mouth of the fiord, must be supposed to originate in the heated Polar water above the coast shoal, which must then have extended into the fiord. The cold water above 50 m. must be on the point of flowing out of the fiord, whereas the cold water in about 100 m. must be supposed to be nearly stationary.

As far as is known neither of the latter fiords is connected with the warm Atlantic water by means of deeper channels through the coast shoals, and, at any rate as far as Kvanefiord is concerned, the depth outside the mouth of the fiord does not amount to much more than 100 m. The warm under layer which, nevertheless, occurs in the two fiords, shows that the low salinity current, the autumn continuation of the Polar Current, at any rate now and again decreases so strongly in thickness that the Atlantic water covers the banks off this part of the coast; from what we have seen in the above, this can, however, hardly take place till late in the autumn.

Outside *Fiskenæsfiord* the depth of the coast shoal is only about 50 m. In the interior of the fiord there are depths of more than 300 m., and here the "Tjalfe" Expedition, below 75 m., only found temperatures of less than 0°. From 100 to 300 m. the temperature was rather constant (-0.15 to $-0.19°$), and this also holds good of the salinity (about 33 $^0/_{00}$) which seems to suggest that the winter cooling from the surface plays a part in the

distribution of temperatures. In the outer part of the fiord, which consists of a system of sounds, there were as early as the latter part of June 1909, down to a depth of about 100 m., temperatures of 1° or more together with a lower salinity, which seems to suggest that the tidal currents have carried water masses in here from the coast current and caused the dilution or renewal of the water down to the depth mentioned above.

In *Godthaab Fiord* researches were undertaken by Ryder in 1885 and by the "Tjalfe" Expedition in 1908. The latter investigations are represented in the innermost part of the section of fig. 6, which shows that at St. 28, at the mouth of the fiord off Kangeq, where the depth is about 400 m. there is a nearly constant temperature of about 0.6°, and also a more or less constant salinity of 33.3—33.4 ‰. The surface temperature increases in the direction of the interior of the fiord and is about 2° at St. 26 off Sârdloq, where the depth is a little more than 400 m.; at St. 27 in the sound outside Qôrnoq (about 600 m.) the surface temperature exceeds 4°, and here we find an immense water layer, from 75 to 250 m., the temperature of which is below 0°.

Whereas the salinity of the cold water in the more southerly fiords increases strongly downwards, we find in the Godthaab Fiord a constant salinity downwards through the cold water, which shows that the latter has been subjected to strong vertical processes of mixture, presumably brought about by the cooling of the surface in winter, possibly in connection with the strong tidal currents in the many sounds into which the fiord divides. At depths exceeding 250 m. the temperature is positive, and in the greatest investigated depth, 550 m., a temperature of 1.12° was found, which in connection with the low salinity (33.57 ‰) shows that the bottom water is a composite product, the Atlantic component of which is not the dominating one, as in Kvanefiord and the more southerly warm water fiords.

Ryder (see Jensen 1889, p. 97) found lower temperatures in the bottom water than the above-mentioned values; off Sârdloq there is thus a record of 0.4° in about 500 m., whereas the researches of Ryder show that the heating extends far downwards in the course of the summer. Unfortunately, the water bottle used does not seem to have worked very satisfactorily.

Angmassivik (north of Fiskefiord) and *Sermilik* (at Sukkertoppen) were investigated in 1885 by J. A. D. Jensen (1889, pp. 84 and 78). In the former fiord, which has depths of about 300 m., there occurred, at the end of July, a surface layer with a positive temperature amounting to upwards of 100 m., whereas the bottom layer had a fairly constant temperature, *viz.* —0.2° to —0.3°. In Sermilik the bottom temperature at 136 m. was —1.5°, and there were only positive temperatures down to about 25 m. As already stated, the cold layers in these latitudes hardly originate in the Polar water, and the low temperature in the bottom layer of the fiord must be supposed to be caused by the cooling during the winter. The determinations of salinity are,

as in the greater part of former researches, rather casual, but they seem to show that the salinity of the cold bottom water is about 33.5 $^0/_{00}$.

Through the deep channel separating Great and Little Hellefiske Bank comparatively warm water is, in all probability, discharged into *Ikertôq* and *Amerdloq* south of Holsteinsborg, at any rate judging by conditions at "Tjalfe" St. 112, at the mouth of Amerdloq (see fig. 10). The latter, which was examined in May, 1909, shows (as also appeared from researches undertaken at the same place in August, 1908) that the temperature of the bottom water was higher in May than in August.

As regards the large fiords between Holsteinsborg and Egedesminde researches are only at hand from *North Strömfiord*. Here Jensen (1881, p. 137) in 1879 undertook numerous measurings, showing variable, though positive temperatures in the under layer, down to the greatest depths (475 m.). This seems rather inexplicable, as we have seen that the warm water, which in summer is to be found outside the fiord on Great Hellefiske Bank, is of low salinity and thus cannot form the bottom water of the deep fiord, whereas the cold water, which in winter is found above the bank, has a salinity of about 34 $^0/_{00}$ and so must necessarily displace the warmer bottom water of the fiord. Consequently, it seems likely that the values recorded by Nordmann in 1911 (see Stephensen, 1914, p. 59) occur, which values everywhere at greater depths than about 50 m. show a negative temperature; the lowest value found by Nordmann was —1.5.

3. BAFFIN BAY.

Through several sounds, the most important being Lancaster Sound, Jones Sound and Smith Sound, with the Kennedy and Robeson Channels, Baffin Bay communicates with the Arctic Sea, but on account of their comparatively small breadth these sounds are of less importance than Davis Strait, running between Greenland and Baffin Land and connecting Baffin Bay with the Atlantic.

In Davis Strait the above-mentioned continuation of the North-Atlantic Ridge occurs, this ridge, in the deepest part of the strait, presumably lying about 600 m. below the surface of the sea, and thus making an effective division between the deepest parts of Baffin Bay and the sea west of the southern part of Greenland. Just as the temperature of the bottom water of the Greenland Sea is about 4° lower than that of the bottom water south of the Atlantic Ridge, we here on both sides of the Greenland-Baffin Land Ridge meet with a great difference in the temperatures of the lowest water layers.

To the exchange of the upper water masses the above-mentioned ridge naturally forms no obstacle. In the western part of Davis Strait we find an analogy to the East Greenland Polar Current of the Greenland Sea, *viz.*

the ice-carrying current, which farther south is known by the name of Labrador Current. This current may partly be said to proceed from the Arctic Sea, seeing that from the ice-drift in the above sounds the current in the latter is known to flow inwards, in the direction of Baffin Bay, but Labrador Current undoubtedly only attains its present extent, because it carries the ice formed in this place away from Baffin Bay, as well as the surface layer which has been cooled during the winter. This south-going Polar Current is shown in the western part of fig. 10, which is based upon the measurings of "Tjalfe", May, 1909. We see that the tempera-

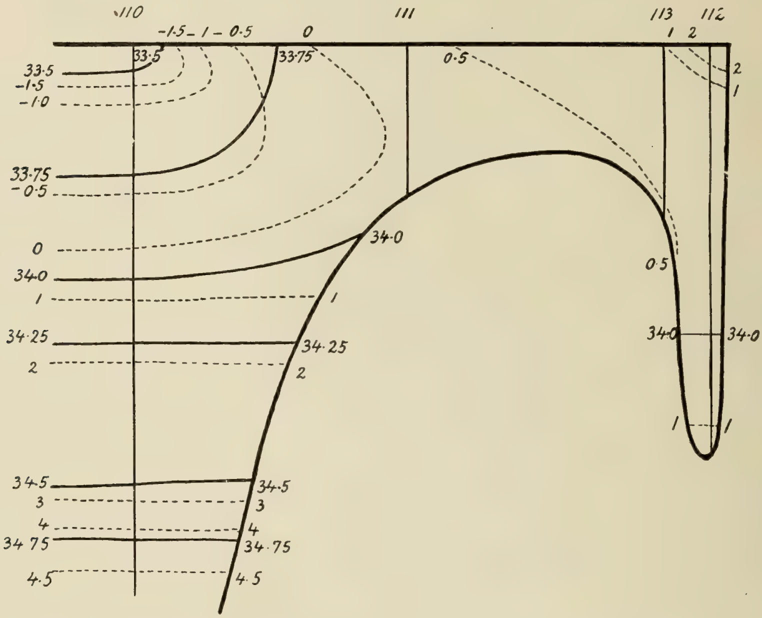

Fig. 10. Horizontal Scale: 1 mm = 2 km. Vertical Scale: 1 mm = 5 m.

ture of the surface lies very near the freezing point of the water, and the temperature is negative to about 150 m.; earlier investigations ("Ingolf" and "Fylla") yield a greater vertical thickness of the Polar Current, i. e. a little more than 200 m.

Beneath the cold, south-going Polar Current we likewise meet with warm water, warmer indeed than that found at this time of the year beneath the Polar Current off South west Greenland; at a depth of 350 m. the temperature thus exceeds 4.5°, and at 400 m. we even find a value as high as 4.8°; then the temperature decreases downwards, though at the bottom (a little more than 600 m.) it is still a little higher than 3°. The salinity of the warmest water amounts to 34.9 $^0/_{00}$, and it thus appears that both temperature and salinity in the warm under layer of the Labrador Current greatly approach to the values which in the autumn are met with in the warm,

intermediate layer off the south-west coast of Greenland. Whereas the movement of the upper and the intermediate layers in this place was in the same direction, there is no doubt that the warm under layer of the narrowest part of Davis Strait must run in the opposite direction to that of the surface current, seeing that the under layer must necessarily proceed from the south.

As the warm under layer is to be found in the narrowest and shallowest part of the strait, with a north-going movement, it is to be expected that this under layer runs on into Baffin Bay, and at all the deeper stations in the northern part of fig. 5 we therefore find a comparatively warm under layer, which can only have been carried here by the under current through Davis Strait. Temperature as well as salinity is, however, considerably lower than in the under current of Davis Strait, from which it appears that the water from the latter undergoes a rather strong cooling and partial dilution before it spreads over Baffin Bay, *but in any case in the whole of the eastern part of the latter there is a warm under layer, which has been carried here through Davis Strait from the Atlantic.*

At St. 41 (fig. 5) north of Great Hellefiske Bank we thus, below 200 m., meet with a salinity of more than 34 $^0/_{00}$ and a temperature of more than 1°; at the bottom (425 m.) even 1.72°. At St. 57 off Hare Island the temperature at the bottom still exceeds 1°, and at Hamberg's St. 17 in the Melville Bay south of Cape York the temperature at 400—500 m. is 0.9°. The measurings of Ryder in the Upernivik Icefiord show that the temperature in winter is positive below 375 m., but these measurings seem less reliable (−2.0° at 19 m.), and this also applies to the measurings undertaken at smaller depths.

The whole of Baffin Bay is in winter covered by ice for a period of several months, and beneath the ice there is, as in the Arctic Sea and the western part of the Greenland Sea, a water layer cooled to its freezing point. The salinity of the surface layer is somewhat lower than in the Norwegian Sea, seeing that in Baffin Bay we find a salinity of the coldest water of nearly 33.4 $^0/_{00}$, whereas in the East Greenland Polar Current we found, as already mentioned, the value of 34 $^0/_{00}$, and as in the case of the East Greenland Polar Current it must be supposed that the salinity of the whole of the surface layer in winter is of nearly the same value.

The thickness of the cold upper layer is very different at the various stations of fig. 5; at St. 41 it thus only attains about 125 m., whereas north of the Disko shoal it reaches deeper down than 200 m. The thickness undoubtedly decreases in the course of the summer, because the cold surface layer throws off water to the Labrador Current, but there is no doubt that the cold surface layer is maintained all the year round in by far the greater part of Baffin Bay. Only at a few of the shallow coastal banks will the temperature in the course of the summer rise above 0°; at St. 59, west of Disko

Island, there was thus in August, 1908, only quite a thin layer with a negative temperature, which undoubtedly disappears entirely, before the cooling begins again.

South of Cape York Hamberg, at his St. 17, found negative temperatures down to 200 m. and then from 200—500 m. a layer with a positive temperature, whereas 1½ degree of latitude farther south he found negative temperatures down to about 600 m., but still the value of 0.4 at 700 m.; then the temperature decreased from —0.1° to —0.3° from 1000 m. to 1450 m. There is consequently reason to suppose *that the under current through Davis Strait, by the rotation of the earth, is deflected eastwards in the direction of the west coast of Greenland, and that the warmest water is therefore to be found nearest the latter.*

Whether the comparatively warm intermediate layer occurring in the eastern part of Baffin Bay extends over the whole of this bay, we do not know, as the measurings undertaken before Hamberg were carried out by means of methods which cannot supply any information on this point. It is possible that it is not to be found in the central part of Baffin Bay, and even though it does not occur there, it is difficult to explain how the bottom water with a negative temperature is formed.

Our determinations of salinity in the deep Ũmánaq Fiord show that the maximum value in the intermediate layer with a temperature of about 1° amounts to 34.5 ‰, and the salinity of the bottom water must consequently be higher than 34.4 ‰ in order that the intermediate layer may exist as such without sinking right down to the bottom. However, as has already been mentioned above, the salinity of the cold surface layer in winter may be estimated at about 33.4 ‰, and even though it is perhaps somewhat higher in the central part of Baffin Bay than at the east side, where the surface water in the course of the summer is greatly diluted through the admixture of melting water, it is not very probable that the salinity of the upper layer should be 1 ‰ higher in the middle of the fairway. *But unless such a value occurs, the bottom water cannot be formed in Baffin Bay itself,* for if the salinity of the upper layer is lower than 34.3 ‰ it cannot, through being mixed with the warmer intermediate layer, yield a composite product sufficiently heavy to form bottom water.

Owing to our lack of knowledge of the hydrographical conditions we are thus unable to determine how the bottom water of Baffin Bay is formed. As a possibility, which seems a very likely one, it shall be mentioned that the bottom water of Baffin Bay may have come down here through the sounds to the west of Greenland. In these sounds the depth, as mentioned above, is presumably a couple of hundred metres, and as the surface current runs towards the south, it is likely that this applies to the whole of the water layer in the sounds. In the Arctic Sea the salinity, even at 150 m., exceeds 34.5 ‰, and the temperature is below 0° down to depths of 200 m. or per-

haps a little more, for which reason it seems likely to suppose that the bottom water of Baffin Bay proceeds from the lower part of the cold upper layer of the Arctic Sea.

This is contrary to the opinion set forth by Moss and Nares, who held that there was an under current of Atlantic origin, running from Smith Sound through the sounds farther north. On closer investigation, however, it turns out to be a mere supposition, the basis of which is even very doubtful; the highest temperature found by Moss (1878, p. 545) in the under layer of Kane's Basin was —0.6° (at about 210 m.) and from the rapid increase of the density with the depth Nares concludes that the bottom water must be Atlantic water from the south, starting, as it seems, from the erroneous supposition that the waters of the Arctic Sea have a very low salinity. If, however, the salinity is computed from the determination of density at 200 m. the value found is 34.73 $^0/_{00}$, and in case this value is considered decisive, we consequently arrive at the conclusion *that the salinity is so high as to prove that this water cannot have come from the south through Smith Sound, but must originate at depths of 150—200 m. in the Arctic Sea.*

It was mentioned above that the cold surface layer in the summer of 1908 disappeared on the coast shoal west of Disko Island. This occurred early in the summer over Great Hellefiske Bank, and it is consequently not to be wondered at that the cold upper layer also disappears from the deeper waters west of Egedesminde.

From fig. 11, which represents measurings undertaken in this place from the "Tjalfe," on July 9th (St. 42) and August 17th (St. 61) respectively, it appears that the characteristic temperature minimum still occurred on the former date. The temperature was, however, already at that time 1° higher than 30 miles farther towards west-south-west, at St. 41 (see fig. 5). On the resumption of the investigations in August the cold water had disappeared entirely, and as it was still to be found south-east of Disko as well as to the west of St. 41, the disappearance of the temperature minimum is not only due to its being heated in the place, but also to the influx of warmer water masses. As the salinity has decreased somewhat, it cannot be Atlantic water, *but the new upper layer must originate in the water masses heated over Great Hellefiske Bank.*

On the east side of Disko Bay there were in the month of July positive temperatures at all depths (fig. 12, St. 47), whereas in the greater part of the bay there was less than —1° in the upper layer. As early as the end of July the water heated over Great Hellefiske Bank has already displaced the cold upper layer from the east side of the southern part of Disko Bay, and we must consequently conclude that there is a north-going current off the central part of the west coast of Greenland as well as off the southern part.

We have already seen that the Polar Current from South Greenland

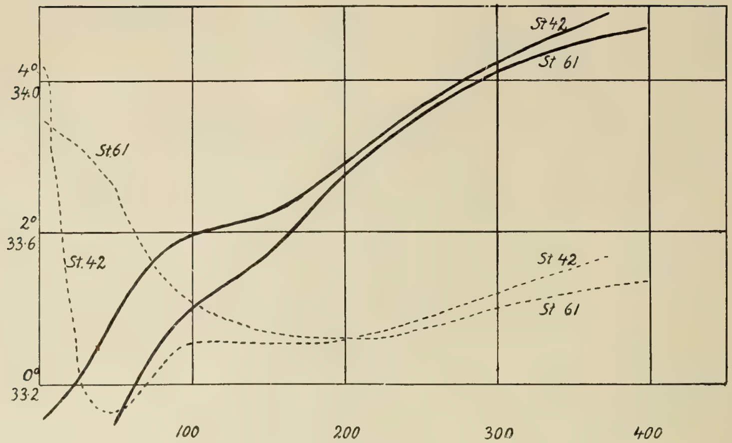

Fig. 11.

off Godthaab spreads towards the west, and the surface current above Great and Little Hellefiske Bank can consequently only originate in a continuation of part of the water masses of the Polar Current, which in their course are heated to a comparatively high temperature. We thus arrive at the result

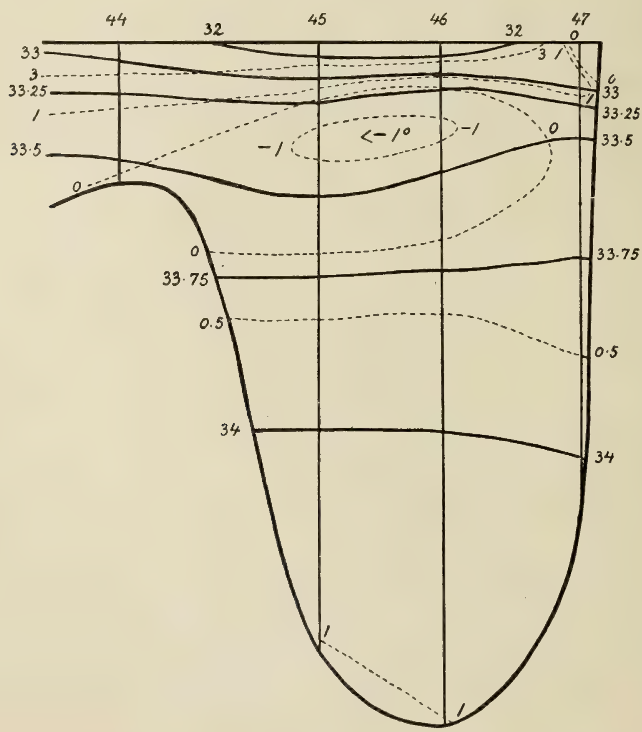

Fig. 12. Horizontal Scale: 1 mm = 2 km. Vertical Scale: 1 mm = 5 m.

that water masses *extend all the way up to Disko Bay, having been carried from the Polar Basin by means of the East Greenland Polar Current;* after the ice has melted off—which most frequently occurs before it reaches Godthaab—the water is heated, so that above Great and Little Hellefiske Bank and on the east side of Disko Bay it appears as a warm current in comparison with the water masses to be found there. Sometimes, however, the Polar Current may undoubtedly carry cold water farther north; there are instances at hand of the ice having extended much farther—in 1896 it thus reached as far as Egedesminde.

The warm under layer on the east side of Baffin Bay (see fig. 5) also extends into Disko Bay, where in fig. 12 we find a rather thick bottom layer with a salinity exceeding 34 $^0/_{00}$ and a temperature of about 1°. Consequently, though there are several islands and skerries at the mouth of Disko Bay, there must in some place or other between the latter be a sufficiently great depth to permit of the warm under layer occurring north of Great Hellefiske Bank and penetrating into Disko Bay. It must, however, be supposed that the depth of this submarine channel of communication is not so great as in the interior of Disko Bay (about 400 m.) seeing that the temperature, in this place, is a good deal lower than at the stations north of Great Hellefiske Bank. Former investigations, however, show higher temperatures for the bottom water of Disko Bay than those found by the "Tjalfe"; in 1884 the "Fylla" thus found a bottom temperature exceeding 2° (Wandel 1893, p. 66).

The warm upper layer flowing into the eastern part of Disko Bay is cooled by its passage between the icebergs on the Jacobshavn Bank, so that directly to the north of the latter there was again in July, 1908, an intermediate temperature minimum below 0°. The north-going upper layer is, however, diluted with the melting water from the icebergs and thus, in spite of the cooling, becomes lighter and rises somewhat; the bottom temperature is of course not influenced by this dilution, and we consequently find as high a temperature at the bottom, north of the iceberg bank, as in the same depth south of the latter. The warm bottom layer extends towards the north, through the Vaigat, as, judging by measurings between Ritenbenk and Disko, the temperature slowly decreases towards the north.

In *Jacobshavn Icefiord* there is, as in Disko Bay, a warm under layer; by means of measurings carried out in November, 1879, Hammer (1893, p. 28), found positive temperatures everywhere at depths of a little more than 100 m., and in the greatest depth investigated (461 m.) the value was 1.3°. Even in the shallower branch, Tasiussaq, a positive temperature was recorded at the bottom in May, 1880.

In *Ũmánaq Fiord* where there are depths exceeding 700 m., the "Tjalfe" Expedition found from 500—700 m. a nearly constant salinity of 34.5 $^0/_{00}$ and a temperature of 1° or a little more. This is the highest value of salinity on

record north of the ridge, and when no such high values have been found at the other stations of Baffin Bay, this is undoubtedly due to the fact that these have not been deep enough to show water of the highest salinity. Seeing that this water is able to penetrate into Ũmánaq Fiord, it must be supposed that the latter continues as a submarine fiord through the coast shoal, with depths of 500 m. or more.

In *Upernivik Icefiord* Ryder (1889, p. 239), as already mentioned, in the month of January also found positive temperatures below 375 m.; in the summer, at depths of 100 m., he even found a temperature of 2° beneath a cold upper layer, which observation, however, can hardly be supposed to be quite correct, until corroborated through further researches.

As the warm intermediate layer from Baffin Bay has penetrated into and forms the under layer at all the deeper fiords where investigations have been carried on, it is probable that it is to be found in all the Greenland fiords abutting on Baffin Bay, unless the fiord, through a threshold of no great depth, is cut off from the warm intermediate layer. In these fiords the upper layer with a negative temperature is maintained all the year round, which is conditioned by the strong supply of melting water in the summer, seeing that in this manner a low salinity surface layer, often less than 30 $^0/_{00}$, comes into existence, the low density of which only permits slight intermixture with the cold water below it, and as the fresh surface layer quickly flows out of the fiord, it prevents the cold water from being sufficiently heated from the surface.

Before leaving Baffin Bay I shall briefly state the ideas formerly held of the hydrographical conditions of this bay. There is no doubt that in former times the action of the solar radiation in the Polar regions was much underestimated, and wherever in these regions a heavy ice cover disappeared in summer, the reason was directly looked for in a warm current.

As several Polar expeditions during the summer found open and rather ice-free water in Melville Bay and even in Smith Sound, Petermann drew the conclusion that this must be owing to a warm current, and on the strength of this (1867, p. 176) he set forth the supposition that the "Gulf Stream," from the regions north-east of Newfoundland, threw off a branch along the west coast of Greenland, passing through Davis Strait and Baffin Bay, all the way up to Melville Bay and Smith Sound. The destruction of the ice masses of the East Greenland Polar Current, as well as that of the ice in Melville Bay and Smith Sound, would then have to be attributed to this branch of the "Gulf Stream."

Bessels, who a few years later undertook researches in these regions, however, finds nothing to confirm the hypothesis of Petermann and says about the latter (1876, p. 6): "There is nothing to support this view; there is not the slightest trace of a warm current in the vicinity of Smith Sound."

As previously stated Moss and Nares found everywhere in Smith Sound

and north of the latter a cold upper layer, but seeing that, as already mentioned, their observations yield no support for the theory of the existence of a warm under current, I am inclined to believe that the hypothesis of Petermann has contributed towards making them form the supposition of the existence of such a current.

In the light of what has been shown by subsequent investigations as to the intermediate layer in Baffin Bay, the remark of Bessels, as quoted above, seems rather strong, but we must bear in mind that Petermann speaks of a *surface current*, and that it is this idea which Bessels reduces *in absurdum*. If, on the other hand, we are thinking of the intermediate water masses, the current system as conceived by Petermann is in the main correct. However, the warm water passes from the regions north-east of Newfoundland to the northern part of Denmark Strait, before it reaches the west coast of Greenland, but from there its motion is analogous to the surface current presumed by Petermann.

It is, however, impossible to lay too much stress upon the fact *that the Atlantic water is not to be found in the surface, but is divided from the latter by a cold surface layer, which in Baffin Bay has a negative temperature all the year round;* consequently, the warm water can exercise no influence on the ice conditions of Melville Bay or Smith Sound, and thus the whole basis of Petermann's theory comes to naught. But, however strange it may sound, the result he arrives at, though starting from erroneous presuppositions, may partly be called a correct one, in so far as up to Melville Bay there runs a warm intermediate current of Atlantic water; but Petermann did not know—and at the time could not know—anything of the existence of the intermediate current.

GENERAL REMARKS.

As demonstrated in the preceding, the East Greenland Polar Current conveys ice and water masses from the Polar Basin along the whole of the east coast of Greenland as far as Cape Farewell, where it deflects in a northerly direction along the west coast. Towards Godthaab the ice as a rule has melted off, and part of the water masses of the Polar Current deflect towards the west, whereas the remainder continues along the coast and can still be traced in Disko Bay. North of Godthaab it has generally lost the negative temperature characteristic of a Polar current, and by being heated and diluted with melting water from the land it gradually assumes the character of a coast current of low salinity and a comparatively high temperature, so that there is full justification for the statement that *the Polar Current as such only exceptionally reaches beyond Godthaab.*

The *velocity* of the Polar Current is only imperfectly known and undoubtedly varies in various places, just as it evidently changes with the season.

The most reliable information is to be traced back to ships, beset by the ice and drifting with the latter, or to people who have been carried along the coast on ice floes.

On the strength of these observations, as well as those made by the "Belgica" Expedition in 1905, Helland-Hansen and Koefoed (1909, p. 23—28) arrive at the conclusion that the velocity of the Polar Current in the Greenland Sea is greatest above the continental edge, where in summer, at the surface, it amounts to 10—14 miles within the twenty-four hours, while it is only half as great off the coast of Greenland. The velocity must be supposed to be smaller in winter than in summer, and it further decreases with the depth below the surface; in the intermediate water layer it is presumably several times as small as at the surface, but as to this there are no indications.

South of Denmark Strait, where the Polar Current narrows considerably, its velocity becomes greater, and during the summer it is estimated at about 1 mile an hour. In the autumn the velocity decreases, and the values found at the period when the ice again appears off Angmagssalik and Cape Farewell are much smaller (from 5—16 miles within the twenty-four hours), but it is a matter of course that this manner of computation only yields a lower limit of velocity, as melting-off evidently still takes place at this time of the year on the stretch travelled.

As far as the intermediate warm water is concerned we are able to form an idea of the velocity of the current off South Greenland. It has already been mentioned that a temperature of more than 6° occurs off Fiskernæsset, and seeing that water with such a high temperature can hardly be supposed to have left the northern part of Denmark Strait before the end of May, we are led to the conclusion that this water has moved with a velocity of about 8 miles within the twenty-four hours.

The values to be deduced from the drift of the ice off South-west Greenland are very variable, which is not surprising, as the ice occurring in this place quickly melts off. On the west coast the velocity of the current is, however, presumably somewhat smaller than off the southern part of the east coast, and there is hardly any doubt that the part of the Polar Current which leaves the coast in the vicinity of Godthaab, only turns away because the velocity of the current has decreased, so that the deflecting influence of the rotation of the earth cannot balance the forces which attempt to remove the lighter water from the coast. In the coast current which proceeds farther north, the velocity, on the other hand, continues to be great, but on account of the constantly occurring changes it is difficult to find any basis for a determination of the velocity.

The velocity of the surface current off the coasts of Greenland, besides being dependent upon the prevailing winds, is also dependent upon the tidal movement. The tidal wave from the Atlantic runs towards the north

on both sides of Greenland and thus strengthens the surface current off the west coast, while diminishing the velocity of the current off the east coast. The tidal movement is strongest close to the coast: off the northern part of the east coast, where the velocity of the current decreases towards land, the flood current is stronger than the coast current and consequently alters it so as to make it faintly north-going. The ebb current, on the other hand, strengthens the Polar Current along the east coast and diminishes the velocity of the current along the west coast.

The difference between high and low water decreases on an average from south to north; at spring-tide it is 12.5 ft. off Frederikshaab, 8 ft. off Upernivik and 5 ft. in Polaris Bay (Robeson Channel), but it is clear that this difference is greatly dependent on the position of the place. This, in a still higher degree, applies to the velocity of the tidal currents; it is thus well known that at the mouth of North and South Strömfiord there is a rapid current, which changes its direction after having been momentarily stationary.

In the preceding we have repeatedly touched upon the fact that the *ice conditions* off the coasts of Greenland change greatly in the course of the year; furthermore, they also vary considerably from one year to another, and the following attempt at a short summary of the yearly variation can, of course, only be regarded as approximate, seeing that conditions may vary greatly from one year to another.

The ice conditions off East Greenland north of Denmark Strait have already been touched upon (p. 191—192), and this part of the coast being uninhabited, our knowledge of the ice conditions is of rather a desultory character; however, it is to be supposed that "Storis" occurs all the year round on the whole of the stretch, even though it may be separated from the coast by a broad belt of ice-free water.

Off Angmagssalik "Storis" still occurs during the greater part of the year, but there are some autumn months when the sea is entirely or rather free from ice. The ice disappears most frequently in August or September, sometimes as early as the month of July, but also after this time of the year it now and then happens that scattered ice or continuous ice bars pass along the coast. In November heavy "Storis" usually reappears, and during the greater part of the winter it remains joined to the land, though now and again it is broken by heavy gales.

At Cape Farewell the occurrence of the Polar ice is subject to greater fluctuations from one year to another. According to the Danish Nautical-Meteorological Annual of 1913 (p. XXII) the first "Storis" in the sixteen years from 1898—1913 passed Cape Farewell at the earliest on November 23rd (1903), and at the latest on March 5th (1906). Within this period of sixteen years the first "Storis" for three years appeared before the first of January, for five years in the month of January, for six in February and for two during the first days of March; the mean of the sixteen years is January

25th, but this is naturally of no great importance, seeing that the mean error on this date is considerable.

From Cape Farewell the "Storis," as already mentioned, drifts up along the south-west coast of Greenland where, however, it rarely freezes up and forms land ice as off Angmagssalik. The ice appearing at an early period off Cape Farewell as a rule does not reach very far north off the west coast, which is presumably due to the fact that it quickly melts in the still comparatively warm water.

The "Storis" off South-west Greenland generally obtains its greatest expanse in the months of May and June, when it frequently reaches as far as Godthaab. Its position is, however, very variable; lying now as a more or less continuous belt, divided from land by open water, now close inland, and now again covering larger or smaller areas in the shape of closely packed ice divided by water, which is comparatively free from ice.

In June the extent of the ice begins to decrease, and in July it rarely reaches north of lat. 62° N. Off Frederikshaab, and particularly in the Julianehaab District, "Storis" frequently occurs in the month of August, and even as late as October the occurrence of small quantities of "Storis" off Cape Farewell is on record.

From what has been stated above, it appears that the "Storis" principally occurs in summer off South-west Greenland. On the northern part of the west coast, which is not reached by the "Storis", the sea freezes over in winter; in the Holsteinsborg District the ice on the sea is, however, not always reliable, and it may even happen that the ice in Disko Bay is not transversable at any time during the winter. The duration of the freezing-up of course increases towards the north, but the time when the ice settles and breaks up varies greatly. The "west ice" (i. e. the ice from the western part of Baffin Bay) frequently reaches as far as Disko or the Egedesminde and Holsteinsborg Districts, where, however, it only appears during the winter months.

The great difference in the ice conditions from one year to another is undoubtedly due rather to meteorological than to hydrographical causes. For the freezing-up of West Greenland, wind conditions as well as the winter temperature play a part; thus at Jacobshavn the mean temperature in the coldest month (February) varies about 10° on either side of the normal (−18.8°) and it is evident that ice conditions must vary greatly, according as the temperature of the month has been −9° or −29°.

In the Arctic Sea and off the northern part of East Greenland the winter temperature, as a rule, is hardly subject to such great changes, and the quantity of "Storis" off South Greenland evidently depends rather upon wind conditions along East Greenland than upon temperatures. Unfortunately the daily synoptic charts of the distribution of the atmospheric pressure contain no observations from parts sufficiently far north of the

east coast of Greenland so as to make it possible to explain the variations in the quantity of "Storis." As a case in point it may, however, be mentioned that the distribution of the mean atmospheric pressure in June, 1909, was very different from the normal, and that southerly and south—easterly, instead of north—easterly winds prevailed off the southern part of East Greenland. Thus the passage of ice towards the south was stopped, and in that year an exceptional state of affairs made itself felt, the whole of the coast to the south of Angmagssalik being practically free from ice as early as in the month of July. In the same manner the position of the ice off South-west Greenland depends upon the winds; northerly and easterly winds remove it from land, whereas south-westerly winds keep the ice close to the shore.

In the preceding we have only dealt with the sea ice, but it is well known that off the coasts of Greenland numerous "icebergs" occur, having been carried out to sea from the inland ice. The occurrence of these icebergs is of a much more casual nature, though they are to be met with anywhere and at any season off the coasts of Greenland.

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THE GEOLOGY OF GREENLAND

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The present time is a favourable one for the elaboration of a complete account of the geology of Greenland, as it is, for the first time, possible to give a summary of the conditions of the whole country. Through the expeditions of recent years we have arrived so far that no large area is entirely unknown, whereas in all earlier maps the most northerly parts of the country have been most incompletely charted. On the other hand, many areas, in particular on the east coast, have only been made subject to rather cursory investigations, and it is evident that very much is left for future researches, before a complete geological picture can be obtained.

From a geological point of view Greenland must be said to form part of the large Canadian Archean massive; all the other formations occupy a comparatively limited area, and are grouped in an apparently casual manner round the huge main trunk, as fragments depressed by the great tectonic dislocations and thus protected against the effect of erosion. These younger formations are distinctly related to those of the surrounding countries: the formations of the northwest are, as might be expected, closely akin to those of Ellesmere and Grinnel Land; there are many points of agreement between North-east Greenland and Spitzbergen, and the huge basalt formation of the east and west coast is of the same type as that of Iceland and the Faroes, with which it is also directly connected by a submarine ridge.

ARCHEAN

The Archean formation occupies a very large part of the whole area of Greenland; it may perhaps be estimated at about half of the country free from ice, but when looking at the maps figs. 2—6 one gets the distinct impression that these formations are more particularly to be found in the areas forming the interior part of the country, and that in consequence by far the greater part of the area below the inland ice must consist of this formation. Only in the most northerly parts is it to be supposed (as appears

from the map fig. 3) that large areas of later formations are to be found below the inland ice.

As to details of the distribution of this formation the reader is referred to the maps figs. 1—5. Of the intermediate areas it is only to be observed

Fig. 1. Geological Map of Greenland (Bøggild).

that they are so largely occupied by the Archean formation that there has been no reason to supply geological maps. It holds good of all of them that by far the greater part consists of gneiss, broken by larger or smaller massives of (Algonkian) granite. In a few places, particularly in the southern part

of East Greenland, there are a number of small areas consisting of younger eruptives, but in most places the investigations carried on have not been sufficiently thorough to permit of defining these formations with an approximate degree of accuracy. The only pronounced exceptions are the carboniferous formation in North-east Greenland and the basalt area south of Scoresby Sound, for which see the chapters dealing with the phenomena in question.

It may be said of the Archean formations in Greenland generally that not in a single place have they been made subject to more exact investigations; as a rule, it has merely been noted what kinds of rocks were to be found in a certain place, whereas no attempt has been made to unravel the details of their manner of formation and genesis.

The chief part of the crystalline schists as usual consists of gneiss which occurs in all its varieties, being particularly pure and homogeneous in the Egedesminde and Holsteinsborg Districts. The strike, in many places, varies extremely, but from large areas of West Greenland it is described as passing east-west or northeast-southwest. In the interiors of the great fiords of the east coast it is chiefly north-south, and in the interior parts of Germania Land the rare phenomenon occurs of horizontal layers covering large areas[1]. Mica and hornblende schist are described from a number of different places, generally occuring as secondary strata in the gneiss. In the same manner one also, in many places, comes across talcose schists which have been of great importance to the Greenlanders (soap stone), and which are found in particularly large quantities in the Godthaab District. Granulite and helleflint rocks, which in other countries play such a great part because of their being metalliferous, are practically unknown in Greenland.

Of other rocks and minerals belonging to the crystalline schists may be mentioned marble and dolomite, which upon the whole are rather scarce and only in the southern part of the Egedesminde District occur in fairly thick veins or strata; partly together with the latter there are, in several places, rich embedded masses of actinolite, salite scapolite, etc., and in many different places asbestos occurs, though most frequently only in small quantities and of a rather coarse quality. In many places graphite is to be found in the Archean; particularly well known from of old is an occurrence at the Upernivik settlement, but there are undoubtedly far greater quantities in the southern part of the Egedesminde District and also a very considerable band on Amitsoq Island in the Julianehaab District. (As to the use of this and other valuable minerals see the chapter on "Mining in Greenland").

Veins of pegmatite are recorded as being found in the gneiss in a number of places, but as a rule they do not offer points of special interest, nor are

[1] These and the other following data from the regions traversed by the "Danmark" Expedition, but as yet not described in detail, have kindly been communicated to me by H. Jarner, the geologist of the expedition.

many different minerals known from them. Veins of diabase are in most localities extremely common; only in the Egedesminde and Holsteinsborg Districts are they recorded as very rare; as to their strike nothing definite can be stated.

Bodies of ore are of very sparse occurrence in the Archean formation of Greenland, and most of them are absolutely of no importance. The only one exploited is the cryolite bed at Ivigtût, which, as far as is known, is to be found in a sedimentary gneissic formation, though in such a manner that it is embedded in a shell of granite. Here mention must also be made of the copper ore at Alángorssuaq (the so-called "Josva's Copper Mine" between Ivigtût and Nuǹarssuit). In this place the ore makes a vein in a formation of mica and chlorite schists.

ALGONKIAN

The Algonkian formations, which also elsewhere are very difficult to define with any exactness, are still more uncertain in Greenland, partly because fossiliferous deposits are lacking in most localities, and partly because there are only in a few places sedimentary formations which, with any degree of certainty, can be referred to this formation. Almost everywhere in the Archean a number of larger or smaller massives of granite or other eruptives occur, which massives are not schistose and, consequently, must be essentially younger than the gneissic formations. There are, however, all sorts of stages of transition between the two rocks, and so in many cases it will be quite impossible to distinguish between them, while on the other hand it is naturally not possible to be quite certain that the various investigators in their descriptions and maps have followed the same principle when defining the two formations. As to a number of the granite massives, it holds good that they are particularly conspicuous in the landscape, rising far above the common level (the Gneiss Plain), whereas in other cases they do not manifest themselves in that way. Still, it must be borne in mind that the younger eruptives, which are to be dealt with in the following chapter, also most frequently stand out considerably above the surrounding level. Besides the massives, descriptions are everywhere given of granite veins in the gneiss, but as to their age it will be still more difficult to express any definite opinion.

The distribution of granite is particularly large in the most southerly part of Greenland (fig. 2), where it even surpasses the gneiss in quantity; especially well known in those parts is the "Julianehaab granite," described by Ussing. It is generally said to be light grey, not in the least schistose and with a particular power of resistance against denudation and is referred to a late Algonkian period. On Qeqertarssuaq Island, close to Julianehaab, there is a copper ore bed in the granite, the so-called "Frederik VII's Mine,"

Farther north the attention is especially attracted by the large granite massive, which forms the elevated country from Sukkertoppen and in a northern direction; apart from these are, along the whole of the west coast, only smaller masses which, as mentioned above, in many cases form tall, isolated mountains, among which may be mentioned the Melville Monument and the Devil's Thumb in Melville Bay, both of which were investigated by Lauge Koch. The same author also describes various massives in the regions farthest north, in particular an interesting massive north of Etah, which is composed of several different kinds of eruptive rock.

On the east coast granite seems to occur in particularly large quantities in the most southerly part, and even as far as the country round Angmag-

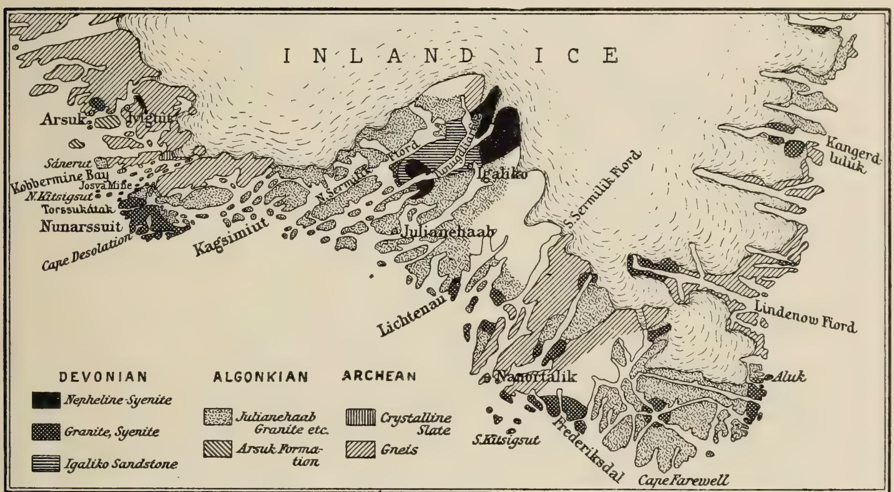

Fig. 2. Geological Map of the southern Part of Greenland (N. V. Ussing).

ssalik it has a fairly large distribution, whereas, according to the accounts, it seems to play a very small part in all the regions farther north.

Of sedimentary formations, which with more or less certainty may be referred to the Algonkian, mention should be made of the following:

The Arsuk formation, partly found on some small islands and partly on the mainland outside Ivigtût (fig. 2). It consists of highly metamorphosed sediments (slates, phyllites, dolomites, quartzites, graphite-schists, metamorphosed diabases and tuffs) in intensively folded strata. Ussing parallels the formation with the late Algonkian (Keeweenawan) rocks of Labrador, but when considering the degree of the metamorphosis, it would seem more natural to ascribe to it a somewhat higher age within the Algonkian.

The Great Sandstone Formation in North Greenland, the knowledge of which has become particularly great through the researches of Lauge Koch (see map. fig. 3 and the table on page 240). On a peneplain comprising the gneiss as well as the above-mentioned eruptives there is in the region

between Cape York and Cape Alexander (the fault zone of the Cape York District), a series of sediments in horizontal or gently inclining strata with a total thickness of 2—400 metres. The rock is largely a red sandstone with the appertaining basal conglomerate and frequently with fine ripple marks; in the upper parts there are also other sediments such as limestone, dolomite, slate and white sandstone. No fossils, which can with any certainty be termed such, have been found. A similar formation occurs on the coast of Inglefield

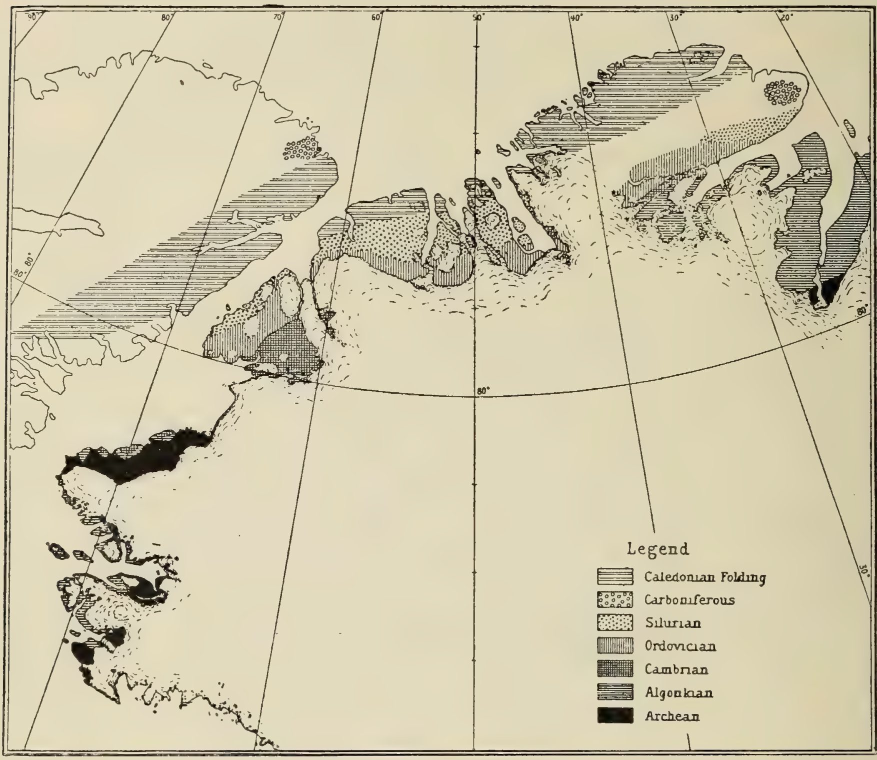

Fig. 3. Geological Map of North Greenland (Lauge Koch).

Land, here chiefly consisting of dolomite and white sandstone. On the other hand, the formation on the south side of Independence Fiord and round Danmark Fiord nearly exclusively consists of red sandstone attaining a height of up to 1000 metres. It is probable that these widely divided occurrences form part of a continuous sandstone plateau below the inland ice, seeing that about midway, on Warming Land, numerous boulders have been found and also a single solid mass of red sandstone.

After the deposition of these sediments abundant eruptions have taken place; in the western area the eruptives chiefly consist of diabase in veins and flows, in the eastern mostly of more acid eruptives.

NEWER ABYSSAL ROCKS

These include a number of larger or smaller massives or veins of granite, syenite, nepheline-syenite or essexite and others which, as compared with the granites mentioned in the preceding chapter, bear an essentially younger impress, so that it is to be supposed that they are of a much more recent date than the Algonkian; their age cannot, however, in any case be determined with certainty.

Like the granites in the preceding chapter the newer eruptives occur in particularly large quantities in the most southerly part of Greenland. Interest chiefly attaches to the nepheline-syenites and the related rocks which are known to occur in three different places (fig. 2), *viz.* about Ivigtût, where the conditions are not described in detail, and the two occurrences recorded by Ussing about Julianehaab, *viz.* the so-called Igaliko and Ilimaussaq batholites. Of these the Ilímaussaq batholite is particularly interesting because of its regular stratification, the upper part consisting of arfvedsonite granite and below that in succession pulaskite, sodalite-foyaite, naujaite, lujavrite and kakortokite, etc. The rocks are arranged in such a manner as to become more and more basic the farther down one gets. Outside this stratified mass there are various other characteristic alkaline rocks, as augitsyenite, nordmarkite and essexite. The Ilímaussaq as well as the Igaliko batholites are distinguished by their wealth of rare minerals. As to the age of these batholites one can only say that they are younger than the Igaliko sandstone (see below), whereas all the other eruptives of South Greenland only verge on the Archean. The greater part of the rocks described above, as distinguished from the Julianehaab granite, crumble very easily, which lends a peculiar character to the surface.

The other younger South Greenland eruptives consist of alkaline granites and syenites, but they have not been subjected to closer investigations; their distribution is particularly great on Nunarssuit Peninsula.

Under this group must also be included the alnoïte described by Nordenskjöld and occurring in Liverpool Land; further, various rocks, described by the same author, from Cape Fletcher and the syenite, described by Nathorst, from Cape Parry on Traill Island (fig. 4).

SEDIMENTARY ROCKS OF UNKNOWN AGE

There are in Greenland a number of different sedimentary formations, in which no fossils have been found, and the age of which cannot be determined in any other way, as they do not immediately verge on formations the age of which is known. To this group belong:

The Igaliko sandstone at Julianehaab (fig. 2); it is red, with nearly horizontal strata; its thickness is about 1200 metres, and it is overlaid

by a series of strata of diabase, about 1000 metres in thickness, the whole of the formation being traversed by the above-mentioned Ilímaussaq batholite. Ussing, who more particularly investigated the formation, is rather inclined to refer it to the Devonian Old Red Sandstone, the nearest occurrence of which is East Greenland (see below). After the above-mentioned North Greenland Algonkian series of red sandstone with numerous eruptives have become known, it may seem rather more natural to refer the Igaliko sandstone to the former, especially as in spite of energetic attempts no distinct fossils have as yet been found in it.

Fig. 4. Geological Map of East Greenland ca. 70—74° l. n. (O. Nordenskiöld).

The sediments of the Jökel Bay (fig. 5) generally consist of loose rocks with lignite, which as a rule is more especially of a Tertiary kind.

Queen Louise Land (fig. 5) in its south-western part contains various sediments, which are rather highly metamorphosed, the strata being horizontal; also eruptives (more especially diorite) occur. The character of the rocks rather suggests the Cambrian-Silurian age.

The Cape Brown and Hurry-Inlet series (fig. 4) consist of sediments, more particularly conglomerates, which by Nordenskjöld are referred to the Triassic.

Cape Fletcher (fig. 4). Here there are a number of different sediments, the whole character of which, according to Nordenskjöld, suggest the Silurian or Devonian age.

The Cape Leslie sandstone (east side of Milne Land) (fig. 4) rather

coarse-grained, red or greyish in gently inclined strata is by Nordenskjöld referred to the Jurassic.

The Red Island conglomerate (west of Milne Land) (fig. 4) is very coarse and of a vivid red colour, the strata being gently inclined. As to the age nothing can be said.

CAMBRIAN—SILURIAN

These formations occur within two different areas, the one occupying the whole of the most northerly part of the country, the other a smaller area on the east coast.

The northern area, which before the voyages of Lauge Koch was very little known, has been subjected to a close investigation by the latter, and large collections of fossils were made from there. As these collections have not as yet been thoroughly examined, the stratigraphy of those parts is not entirely unravelled, and so the statement given below only contains a summary of the already published preliminary results, which possibly may have to be somewhat revised before the final working up of the subject. See map. fig. 3 and the accompanying table.

Fig. 5. Geological Map of East Greenland lat. 74—78° N. (approx) (Bøggild).

The Cambrian formation partly occupies some small areas on the south side of Kane Basin, partly a larger area north of Humboldt Glacier, the so-called "Daugaard Jensen Land," to which must be added an area on the south side of Brønlund Fiord, from where however no fossils are at hand. South of Kane Basin the Cambrian formations overlie the Algonkian sediments and eruptives already mentioned (page. 235—236) which strata have been denuded down into a peneplain before the sea encroached upon them, and the formation here begins with a basal conglomerate with sandstone, the total thickness being 30 metres; then follows limestone with *Olenellus* etc.

Table of the Sequence of Strata in North Greenland

	North America	North Greenland
Silurian	Cayugan	Disconformity
		? Coarse sandstone
	Niagaran	Slate with *Cyrtograptus*
	Oswegan	Slate with *Monograptus lobiferus*
		Disconformity
Ordovician	Cincinatian	? Bumatus limestone
		? Pentamerus leeds
		Disconformity
		? Arethusina leeds
		Disconformity
	Trentonian	Leptaena leeds
		Halysites limestone
		Receptaculites limestone
		Orthoceras limestone
		Beds with *Didymograptus, Isotelus* and *Phyllograptus*
	Canadian	Symphysurus limestone
Cambrian	Saratogian	Intraformational conglomerates with *Ptychopasia*
	Acadian	Limestone with *Dolichometapus* and *Olenoides*
	Georgian	Beds with *Olenellus*
		Disconformity
Algonkian		Dolomite
		White sandstone with diagonal structure
		Cryptozoon limestone
		Purple-red sandstone and basal conglomerate
		Disconformity
		Quartzite with diorite and syenite
		Disconformity
Archean		Uniform grey gneiss

(20 metres), and these Georgian strata are finally overlaid by an Acadian greyish yellow limestone, 40 metres in thickness. The Saratogean strata occupy Daugaard Jensen Land and consist of limestone and conglomerates, 400 metres in thickness and frequently without fossils.

The Ordovician strata, the total thickness of which is 700 metres, have been made subject to particular investigation along the coast of Washington Land. The nature of these strata and of the overlying Silurian ones appears from the above table; the Silurian grapholite slates have a thickness of 500 metres, and the sandstone overlying it a thickness of several hundred metres, being the last deposit before the Caledonian folding; they testify to an incipient uplift, before this folding took place.

It appears from the preliminary investigation that the Cambrian and Ordovician faunae are most nearly related to the corresponding American types, or in a few cases of a cosmopolitan nature; the Silurian fauna, on the other hand, is most closely related to the corresponding European type.

Whereas the above-mentioned strata in the greater part of the area are entirely undisturbed horizontally, they have in the north become highly folded, which folding was shown by Lauge Koch to have taken place in the Devonian period; towards the west the chain continues in across Grinnel Land; towards the east it has its natural continuation in the Caledonian folding chain across Spitzbergen and from there across Norway to Great Britain. In the western part of the Greenland chain the strata are not highly metamorphosed, so that several of the fossiliferous strata mentioned above may be identified in it; in this part of the chain the strata also form distinct and regular folds. In the eastern part the compression has been far more powerful, and so the rocks for the greater part have been metamorphosed into crystalline schists; here also granite massives are to be found. The middle part of the folding chain is traversed by a number of eruptive veins, partly of diabase and partly of porphyry; as to the exact age of the latter nothing can be said with certainty.

The East Greenland area occupies large tracts in the interiors of Franz Joseph Fiord and King Oscar Fiord (fig. 5). They were described by Nathorst, who, however, had little opportunity of investigating conditions more closely; all kinds of sediments occur, and of fossils only very few have been found (ortoceratites, small brachiopods and gastropods) which seem to suggest the Ordovician age. It has not been possible to make out any distinct stratification; the lowermost stratum seems to be an immense deposit of grey sandstone. The strata are greatly dislocated and metamorphosed, though it cannot be discovered with certainty whether any actual folding has taken place.

DEVONIAN

Directly eastward of the above-mentioned area (fig. 5) Nathorst describes Devonian sandstone, red, grey or green and of a thickness of at least

1500 metres; the strata are not greatly dislocated. Of fossils several kinds of fishes (*Holoptychius*, *Osteolepis*) have been found.

CARBONIFEROUS

The Carboniferous formation only occurs within three small areas in the north-eastern extremity of Greenland; two of the latter consist of the small peninsulas south of Northeast Foreland (Holm and Amdrup Land), and more particularly in the former they form the steep Mt. Mallemuk. The occurrence which was visited by the "Danmark" Expedition consists of horizontal strata, at least 1000 metres in thickness; the lowest strata consist of sandstone and shale with remains of plants which have been described by Nathorst and consist of *Lepidodendron* and others belonging to the Lower Carboniferous. Above these there are marine formations, the lower strata chiefly consisting of sandstone, the upper ones of limestone or dolomite, containing a number of fossils, chiefly brachiopods; the latter, which were investigated by Grönwall, are closely related to the Russian-Arctic forms, thus showing that the deposit belongs to the Upper Carboniferous; the genera *Productus* and *Spirifer* predominate.

The third area where the formation occurs is in the eastern part of Peary Land (fig. 3) and was discovered by Lauge Koch. The formation, the thickness of which is about 700 metres, consists of slate, limestone and in the upper strata sandstone; it contains numerous fossils, corals, brachiopods and *Fenestella* and seems to be closely related to the above-mentioned occurrences.

TRIASSIC

This formation only includes a few small occurrences in East Greenland. On the mainland inside the Sabine Island (fig. 5) the Second German Polar Expedition found a sandstone deposit with *Rhynchonella fissicostata* indicating Rhaetic age.

The Flemming Inlet series (fig. 4) consists of various sediments, partly of very vivid colours; traces of fossils occur which, according to a preliminary determination by Grönwall, are referred to the Triassic.

In the lowland between Liverpool Coast and Jameson Land (fig. 4) there is a series of conglomerates without fossils, which, according to their position in relation to the surrounding formations, are referred by Nathorst and Nordenskjöld to the younger Triassic.

Lowest down at Cape Stewart, (fig. 4) and in the coast which forms the northern continuation of the latter there is a sandy slate, about 40 metres in thickness and containing a great number of plant fossils, which by Hartz and Harris have been determined as Rhaetic. The most important

fossils are: Ferns (particularly *Cladophlebis Roesserti*), cycads (particularly *Podozamites*), conifers (particularly *Czekonowskia*).

JURASSIC

This formation occurs in a number of various localities in East Greenland.

At Danmark Harbour on Germania Land (fig. 3) boulders have been found, belonging to the Séquanian-Kimmeridgian and Portlandian (cf. Ravn).

On Koldewey Island (fig. 5) there is (cf. Ravn): 1: Sandstone of the Callowian age; among the not particularly numerous fossils must be noted three different new species of ammonites. 2: Sandstone belonging to the Séquanian-Kimmeridgian with numerous fossils, mostly bivalves (*Aucella*, etc.), gastropods and ammonites.

Hochstetter Foreland (fig. 5) consists of yellow or reddish sandstone with very few fossils, bivalves, gastropods and a single ammonite, *Cardioceras alternans*; on the strength of this the formation, which by the Second German Polar Expedition was considered Tertiary, has by Ravn proved to be of Jurassic age.

From Kuhn Island (fig. 5) the Second German Polar Expedition described two different Jurassie localities; on the south side of the island black sandstone occurs with coal strata, containing a number of not particularly well preserved fossils, chiefly bivalves indicating the middle Dogger. According to later investigations the other locality, on the east side of the island, belongs to the Cretaceous period, though it is not excluded that some of the strata may be of Jurrassic age.

A very small area on the south side of Davy Sound (fig. 4) is by Nathorst referred to the Jurassic formation.

Jameson Land (fig. 4) more particularly described by Bay, Lundgreen, Nathorst, Nordenskjöld and Madsen has probably a substratum of Jurassic deposits rich in fossils and belonging to many different zones; the strata are especially exposed in the cliffs from Cape Stewart and farther north, whereas the remainder, with the exception of a single occurrence (*Aucella river*) on the south-west coast is covered by Quaternary deposits. The rocks are generally more or less calciferous limestones with a nearly horizontal stratification; basalt beds have also been found. The lower strata of the Rhaetic or Rhaeto-Liassic are mentioned in the chapter on Triassic; then follow strata from Lower Bathonian or Upper Bajocian, characterized by various bivalves, more particularly *Ostrea eduliformis*. To the Callovian belong the bulk of the strata, in particular those at Cape Stewart; of the numerous fossils, mention must especially be made of bivalves (*Limea duplicata, Acicula Mönsteri, Leda lacryma, Cardium concinnum*, etc.) and ammonites (*Macrocephalites* species). Strata of Portlandian age occur at Aucella River; they are more particularly characterized by *Aucella Pallasii*.

CRETACEOUS

In East Greenland the lower Cretaceous (Neocomian) is represented by the following areas:

At Danmark Harbour (fig. 5) have been found a few boulders belonging to this formation (Ravn, 1913).

The so-called Aucella Mountain on the east coast of Koldewey Island (fig. 5). The rock is a conglomerate with some very large gneissic boulders, whereas the ground mass chiefly consists of shells of different species of *Aucella* (Ravn 1912).

Fig. 6. Map of the basalt formation of West Greenland (K. J. V. Steenstrup).

On the east side of Kuhn Island (fig. 5) the Second German Polar Expedition found layers of sandstone and marl with various fossils, of which the *Aucellae* suggest the Neocomian age, whereas *Belemnites Panderianus* indicate Dogger (see above).

The Cretaceous formation is far more widely distributed in West Greenland (fig. 6), where it constitutes the basis of a great number of the Tertiary formations on Disko and Nûgssuaq, and it furthermore occurs in Upernivik Island. The rocks are mainly slate and sandstone with secondary layers of lignite, which latter seem to be distributed over the whole extent of the formation, frequently in several successive layers, one above the other; the individual layers may attain a thickness of about one metre (as to the use made of these see the chapter on "Mining"). This formation is particularly famous because of the large quantities of plant fossils contained in it, by means of which Heer has been able to divide them into three series:

The *Kome* (Kûngme) beds consisting of black slates on the north side of Nûgssuaq; they contain about a hundred species, nearly half of which are ferns (chiefly *Gleichenia*), the remainder mostly conifers and cycads; a single dicotyledon (*Populus primaeva*) occurs. The formation is by Heer referred to the Neocomian, but according to more recent investigations it must presumably be considered somewhat younger.

The *Atane* beds, grey and black slates and sandstones, distributed over the whole of the area; they contain about 200 species, of which nearly half are dicotyledons (species of *Populus, Myrica Quercus, Ficus, Magnolia, Platanus, Laurus, Artocarpus* et al.) the remainder mostly ferns and conifers. The layers are by Heer referred to the Cenomanian, but are now considered essentially younger.

The *Patoot* (Pâtût) beds from the south side of Nûgssuaq, chiefly consisting of brick-coloured or yellowish burnt slates; they contain more than 100 species of plants, mostly dicotyledons (essentially the same genera as mentioned above). Besides plants these beds also contain marine fossils, which sometimes are found in lime concretions in the slate and sometimes in the latter itself; most of them are bivalves, among which must especially be noted a number of the *Inoceramus* species and a single Ammonite (*Scaphites Roemeri*). The fauna permits of a more exact age determination than is otherwise possible for the deposits of these regions; according to investigations made by Ravn and others the layers are of Senonian age, and the fauna shows particularly close agreement with a corresponding type from Montana.

TERTIARY

The Tertiary formation occupies a large area of Greenland; in West Greenland it is mainly found on Disko Island and the peninsulas Nûgssuaq and Svartenhuk; in East Greenland it partly fills the large peninsula south of Scoresby Sound and partly a number of the outermost peninsulas and islands farther north (figs. 4, 5 and 6). The greater part of the formation consists of basalt, which has developed in the same peculiar manner as the occurrences on Iceland, the Faroes and certain parts of Great Britain, and it is characterized by the following general features: the whole basalt bulk, the total thickness of which in certain places is as much as about 2000 metres, consists of regular beds, each representing a single lava flow, the thickness of which may reach about 30 metres, and which sometimes may be traced very far in a horizontal direction. The orientation of the beds is everywhere horizontal, except where local disturbances of a later period have made themselves felt. Between the individual basalt beds there are, as a rule, only quite shallow tuff layers, and thicker masses of breccia (*Salissat* at Niaqornat on Nûgssuaq, 300 metres) only rarely occur; the latter may as a rule be supposed to indicate the nearness of a place of eruption, but such are otherwise only mentioned in a single case (Cape Hold-with-hope). Besides occurring as beds the basalt also appears in numerous sills and veins, and in the case of the latter it seems impossible to trace any prevailing direction in Greenland. The basalt itself varies greatly in the size of grains, structure and colour and may be more or less rich in olivine; eruptives of a different composition are extremely rare in the basalt area (trachyte veins

on Ubekendt Eiland south of Svartenhuk, liparite on Cape Hold-with-hope). In its cavities the basalt contains a number of different zeolites; of much greater interest for Greenland is, however, the occurrence of native iron in the basalt on Disko Island and the tracts surrounding it. The greatest iron-blocks were found by Nordenskjöld in 1870 at Uivfaq, west of Godhavn; the largest, weighing about 25 tons, is now in the museum at Stockholm, the second greatest, which weighs 7 tons, in Copenhagen. At first they were considered meteorites, until Steenstrup proved them to be of telluric origin, and it should be mentioned in this context that some of the greatest iron meteorites known have also been found in Greenland, *viz.* near Cape York. They were first mentioned by Ross, and since then various attempts have been made to reach them, until Peary in 1895 and 1896 succeeded in transporting the three then known blocks to New York; one of them weighed about 34 tons, the other two considerably less. At a later period Knud Rasmussen found a fourth stone, weighing about 3.4 tons; by a special expedition it was brought to the shore, from where it was shipped to Copenhagen in the autumn of 1925.

Fossiliferous strata have been found in various parts of the basalt formation; they either occur below the basalt or in the lower part of the latter and may attain a thickness of several hundred metres. The hitherto known occurrences are the following:

West-Greenland (Disko, Nûgssuaq, Svartenhuk, Ingnerit Peninsula, north of the latter, and Hare Island) the rocks being mostly sand and sandstone and clay iron stone. In these formations practically only plant fossils have been found, and the best preserved occur in the iron ore; about 300 species are known, of which there are about 200 dictyledons (*Populus*, *Salix*, *Myrica*, *Alnus*, *Betula*, *Carpinus*, *Corylus*, *Fagus*, *Castanea*, *Quercus*, *Ulmus*, *Platanus*, *Juglans*, *Fraxinus*, *Aralia*, *Vitis*, *Liriodondron*, *Magnolia*, *Acer*, *Ilex* et al.) the remainder mostly conifers: the most common and characteristic species are *Sequoia Langsdorfii Taxodium distichum* and *Populus arctica*. The flora is by Heer referred to the Miocene, by later authors to the Eocene age.

On Sabine Island are found coal layers and slates with plant fossils (*Populus arctica*, *Taxodium distichum*, etc.), on the mainland inside the latter island there are coal layers but no fossils.

In the area south of Scoresby Sound coal layers have only been found in a few places; at Cape Dalton fossils are recorded, being partly remains of the usual plant species in a rather poor state of preservation, and partly animal fossils. The latter, which have been examined by Ravn, chiefly occur in two different strata: The coeloma bed, a slate with lime concretions, containing crabs (*Coeloma and Hoploparia*) besides a few bivalves and gastropods and the cyrenabed a coarse sandstone with gastropods and bivalves in a rather poor state of preservation, among which *Cyrena Gravesi* is particularly common. The fossils show that the deposits are of Eocene age.

QUATERNARY

Quaternary deposits play a comparatively subordinate part in Greenland; most mountain rocks are almost entirely bare of soil, and though valleys and lowlands, it is true, are generally covered, the layers of soil never seem to attain any considerable thickness. The undoubtedly huge masses, which during the glacial period, and later, were carried away from the country by the ice, were largely transported out into the sea. Continuous moraine landscapes of a larger extent are not described, but on the other hand there are, in a number of places, single or complex terminal moraines which very frequently pass right across the valleys. Generally speaking the moraine formations seem to have attained their greatest thickness in the regions round Danmark Fiord and Independence Bay. Stratified deposits also occur in many places; but they only seem to have any great distribution on Jameson Land, where their origin, however, is uncertain (fluvioglacial or marine). The widely distributed raised shell layers are to be mentioned in another context. Among the alluvial formations special mention must be made of the peat, which is very widely distributed in the lower regions, but the thickness of which, as far as is known, rarely exceeds one metre. In quality it is very loose and of little heat power. Drift sand occurs very rarely, as far as is known chiefly on Jameson Land.

GEOLOGICAL HISTORY

Owing to the rather sparse sedimentary deposits, which have not even been made subject to very complete investigation, it is impossible to give any continuous picture of the geological history of Greenland, and so the following should only be considered as a summary of its main features.

The Greenland of the present day appears as a large horst, the structure of which is such that the whole of the central part of the country consists of Archean rock, whereas the younger formations lie scattered along the outskirts. When considering these formations and also their quality it seems probable that conditions have been somewhat similar in all the preceding periods, so that the various transgressions and regressions which have taken place only comprised these outer areas and were of no importance to the totality, for which reason they need not be mentioned in this context. According to the interesting explanations of Lauge Koch the whole of the gneiss area of Greenland consists of two almost equally large sheets, each inclining greatly from south to north. As to the details of this theory see Koch's treatise.

MOVEMENTS OF THE EARTH CRUST.

Foldings. The existence of foldings has only been proved for certain in the most northerly tracts where, as mentioned above (page 241), there is a link of the Caledonian folding chain. Of the possibility of a similar folding occurring in East Greenland mention has been made on page 241.

Faults. It is naturally to be supposed that such have caused the divisions throughout the whole country, and more especially of the gneiss plateau, but as to the detailed course and history of the dislocations themselves very few data are at hand. The most pronounced fault region is in East Greenland, and here Nathorst describes the direction of the dislocations as running predominantly north and south, or in other words, at right angles to the main direction of the fiords. As far as West Greenland is concerned, Kornerup describes diaclases as determining the direction of the coast line and the fjords. A fault zone at Cape York, mentioned by Lauge Koch, is as yet not described in detail.

Slow massive movements. The history of these movements is only to be unravelled as far as the Quaternary age is concerned. When the ice receded, the level of nearly the whole of the country was lower than at present. The amount of the subsidence has been investigated in a number of places, but for the greater part they have not been very exactly determined, and so the picture obtained of the then height of the country becomes rather irregular. Still, it is certain that the amount of the upheaval increases considerably from south to north. For the west coast it is in the Julianehaab region about 50 metres; the figure given for Arsuk Island is 94 metres; for the Godthaab District 106 metres, for the Holsteinsborg District about 120 metres, for Vaigat about 130 metres, and for Svartenhuk about 150 metres. For the regions round Smith Sound the figure given is about 320 metres, wheras Bessels in Polaris Bay (at Petermann Fiord) found shell layers and driftwood at the unique height of 1800 ft. (about 550 metres). For East Greenland it is expressly stated that there is no trace whatsoever of any upheaval on the stretch Cape Farewell—Angmagssalik: at Scoresby Sound it is about 70 metres, whereas the figure given for Franz Joseph Fiord is 71 metres (uncertain 125 metres) and in the regions traversed by the "Danmark" Expedition the highest terraces from which exact measures are at hand are about 400 metres, and the same value was found by Freuchen in Valmuedalen within Independence Sound. Any difference in the amount of upheaval for the inner or outer part of the coast land has nowhere been proved with certainty. At least in the region round Disko the country seems to have had its lowest level for a considerable period after the ice had receded, so that the upheaval must have been preceded by a subsidence; on the other hand it must be taken for granted that the upheaval ceased again at a comparatively late period and was followed by

a subsidence which is still going on; this appears from the fact that in numerous places along the Danish part of West Greenland there are dwellings, etc. which are now partly below the level of the sea, where they cannot possibly have been built in the first place. The amount of the upheaval is at most estimated at 1 to 2 metres in the course of a century.

In this chapter is further to be given a summary of what is known of volcanic action and earthquakes in Greenland.

As to the eruptive action within the older periods of the earth the reader is referred to the preceding chapters. In the Tertiary period Greenland was the scene of a particularly strong volcanic action, probably most acute in the earlier part of the period. When this activity ceased cannot be determined for certain, nor can its exact age be precisely fixed; however, it was probably long before the glacial period. As a slight volcanic after-effect can be mentioned the few warm springs to be found here and there; in the basalt area there is Ũnartoq in Disko Fiord of about 10°, one at Mellemfiord of 18,8° and another on Turner Land, south of Scoresby Sound, of 38°. The warmest of all the springs is, however, to be found in the Archean area, *viz.* at Ũnartoq in the Julianehaab District (about 40°), and in Liverpool Land at Scoresby Sound (up to 62°).

Earthquakes do not seem to be very common in Greenland, and none are known which have had a devastating effect. It is impossible to form any general picture of their distribution, as there is extremely little probability of getting information of earthquakes outside the inhabited parts of the country; it seems as if Angmagssalik has been considerably more afflicted than the settlements on the west coast. From the years 1903 to 1913 there is thus an account of several earthquakes at Angmagssalik, some of which were rather severe and of long duration, whereas within the same years only three are reported from the west coast, one from Godthaab and Fiskernæsset, one from Holsteinsborg and one from Disko and its surroundings. From earlier years there are only very few and chance reports of earthquakes on the west coast.

OSCILLATIONS OF CLIMATE

For the Pre-quaternary age information as to the climate of the various periods is chiefly to be derived from the fossil plants; for the plants from the Carboniferous and the Rhaeto-Liassic period it is hardly possible to infer anything except that the climate cannot have been essentially different from that prevailing at the same time over large parts of the globe, as in Central Europe. The Greenland Carboniferous formation is in so far interesting, as it is the most northerly place where Carboniferous plants are known to have been found. As to the Tertiary fossils Heer made an attempt to explain the yearly mean temperature on the strength of these; his results,

however, have been somewhat questioned by other investigators. For the *Kome* and *Atane* beds of the Cretaceous period he finds a subtropical climate with a mean temperature of 20—21°, whereas the *Patoot* beds suggest a somewhat colder climate and the Tertiary strata a still colder one, about 12°. As to the latter part of the Tertiary period, nothing can be known for certain, but on the other hand it is beyond a doubt that the glacial period has made itself very strongly felt in Greenland; nearly the whole of the land which is now free from ice, was then covered by the inland ice forming a continuous sheet, and, as a rule, only isolated peaks, which are still standing out far above the surrounding surface and are generally distinguished by particularly steep alpine forms, have projected above the ice in the form of nunataqs. Also the comparatively large area of northernmost Greenland, which at present is free from ice, shows by the enormous moraine deposits that it has formerly in part been covered with ice. Greenland has had its own glaciation; the ice striae everywhere tend towards the coast, though there are a number of local deviations which are due to the inequalities of the surface. The moraine deposits being, as mentioned above, comparatively small, and besides not particularly well investigated, no traces of interglacial deposits have been found in Greenland.

A complete report of the oscillations of climate after the glacial period has been given by Jensen and Harder; it proves that the oldest layers contain arctic forms such as *Yoldia arctica*, which now no longer lives in the colonized part of Greenland; then there are layers with a fauna suggesting a climate which is not essentially colder than that of the present day (characterized, *inter alia* by *Balanus Homeri*). After that the climate once more becomes arctic with Yoldia clay, which period coincides with the formerly mentioned largest subsidence of the country. Then follows, at a time when the level of the land was not much lower than at the present day, a fauna suggesting a climate essentially milder than the one now prevailing; at that time *Zirphaea crispata* and *Anomia ephippium* were to be found in West Greenland, and in East Greenland *Mytilus edulis* lived in localities many degrees of latitude farther north than at the present day. The period from then and until the present time is characterized by a gradually decreasing temperature.

SURFACE CONDITIONS

As to the surface conditions of Greenland, it is generally not possible to say much else than that the country is on an average high and mountainous; any orographic articulation it is impossible to give, as the whole of the large central part is so entirely covered by the inland ice as hardly to suggest the appearance of the underlying surface. However, conjectures have been set forth to the effect that, on the one hand, the surface is broken and uneven,

on the other, that it is a more homogeneous plateau land, but there seems to be as little justification for the one as for the other of these two theories.

The highest parts of the surface of the country are occupied by the inland ice; on the route of J. P. Koch the height of these parts, according to the preliminary account, is given as up to 2900—3000 metres. The highest mountains are to be found near the east coast, the tallest being in all probability Mt. Forel, north of Angmagssalik (3440 metres). The altitude of Petermann Spitze within Franz Joseph Fiord was by the Germans given as 3480 (or 4267) metres, whereas Nathorst gives the height as 2800 metres. Other high points are Mt. Rigny, south of Scoresby Sound (2385 metres) and Tiningnertôq at Lindenow Fiord (about 2300 metres). West Greenland is considerably lower; the highest points there are to be found in the interiors of the fiords of the Julianehaab District, which are directly connected with the fiords of the east coast; thus a mountain at Ilua Fiord has a height of 2240 metres. In West Greenland proper the highest points are to be found on Upernivik Island, north of Ũmánaq, where a height of 2090 metres has been measured, and on the Akuliaruseq Peninsula inside the latter (2150 metres).

The inland ice forms a huge plateau, which in the shape of a flat, slightly vaulted shield covers the central part of the country; the highest point is in the southern part nearest the east coast, farther north, however, nearest the west coast. The highest altitude observed (2900—3000 metres) is, as mentioned to be found in this place, whereas de Quervain on his more southerly route reached 2505 metres, and Nansen, on his still more southerly, 2720 metres. The surface of the ice is in the whole of the interior extremely even, but the more one approaches its limits the rougher it becomes; as a rule radiating crevices (parallel with the direction of the motion of the ice) predominate, but otherwise conditions differ very much in the various places, and the inequalities are frequently of a much more irregular character. In the interior of the inland ice the substratum is not exposed anywhere; in the outer parts, however, there are numerous mountains, the so-called nunataqs; by far the greater of the latter is Queen Louise Land at the northern part of the east coast.

The character of the surface of the ice-free country is somewhat varying; broadly speaking it is possible to distinguish between the three usual main types, which are, however, connected by all sorts of transitions, *viz.* lowland, plateau land and mountain land. As to the relative distribution of these three land-forms nothing can be said for certain, as it is difficult to draw the line between the individual forms; the mountain land is at any rate the one with the greatest distribution.

The lowland in its typical form, as level country, is represented by the areas where there are horizontal or almost horizontal sediments, and so it only occurs to any considerable extent in the north and east. As examples may be mentioned Northeast Foreland, which is very low and level, but

entirely covered with ice; further, Hochstetter Foreland and Jameson Land; the latter, it is true, is very flat, but cannot in its entirety be termed a lowland, as it rises gradually to heights of up to 1000 metres.

In the Archean area there are also several tracts of various sizes which must be considered lowlands, but their surface is never very even, being everywhere broken by projecting mountains which, owing to the action of the ice, are generally rounded in shape. Of a particularly pronounced character are the so-called "strand-flats," quite low tracts in the immediate vicinity of the coast and frequently also comprising a "Skærgaard," as a rule consisting of very small and low islands. The strand flats are most obvious in such places where the inner country is high, whereas in the opposite case they merge gradually into the main-land.

The distribution of this land-form is very small everywhere in Greenland; in East Greenland its existence is not yet proved, whereas in the west it occurs in many places. As examples may be mentioned the region round Narssaq in the Julianehaab District, stretches on Nunarssuit and Sánerut situated to the north of the latter; further, various places in the Godthaab region and the Holsteinsborg District must be mentioned, where the phenomenon seems to appear in its grandest form.

Considerably larger areas of quite low Archean rock are partly to be found in the northern part of Egedesminde District where the island on which the settlement is situated, as well as most of the surrounding islands and coast stretches, only reach heights of 100 to 200 metres, partly in the Godthaab District, where the whole of the large peninsula north of Godthaab Fiord is described as particularly low with very few isolated mountains, rising up to 200 metres above the surroundings.

A peculiar country which, as it were, forms a transition between the lowland and the following land-forms is the large area, represented by the inner part of the broad ice-free land in the Egedesminde and Holsteinsborg Districts, the outer part of which, by way of contrast, is high and mountainous. This area may rather be described as a low highland, the greater part of which attains a height of about 200 to 400 metres, whereas the higher parts rise to 600 to 700 metres. The surface forms vary to a certain extent; in some places there are level plains, while in other places they contract into extended valley systems. The intermediate low mountains are only rarely steep, but most frequently they are represented by soft and rounded forms, and the underlying rock is generally covered by products of decomposition. The country is extremely rich in lakes, and many of these are, at least during the summer, without outflow and faintly saline, which facts bear upon the particular warm and dry summer of these parts.

The plateau land is in its most typical form connected with the basalt areas of West and East Greenland, the strata being most frequently horizontal or nearly horizontal. Particularly well known are the Disko Island

and the peninsulas Nûgssuaq and Svartenhuk; Disko in particular is regular and, viewed at some distance, appears with a continuous level surface which inclines quite steeply or in faintly indicated terraces towards the sea. When approaching, however, numerous rather broad valleys open up before one, which valleys confine the few horizontal areas, and at a somewhat closer range the profile, in many places, may assume a very irregular aspect. Nûgssuaq is higher as well as more irregular in structure than Disko, and it is more particularly characterized by the large longitudinal valleys traversing it. The heights of the basalt plateaux, as a rule, range from 1000 to 2000 metres.

Outside the basalt area there are also rather considerable tracts of the character of plateaux; here special mention must be made of the greater part of the Ũmánaq District from the eastern part of Nûgssuaq as far as towards Svartenhuk. This region, on an average highest towards the west and inclining somewhat downwards in the direction of the inland ice, is split up into a number of islands and peninsulas, each of them with a level surface and abruptly sloping sides. The greatest height within this district is, as already mentioned, attained by Upernivik Island which, together with the adjacent part of the mainland, appears with purely alpine forms when viewed from the sea and, perhaps, upon the whole can not be included under the plateau land. Other areas of a more or less pronounced plateau form are known from the region of Holsteinsborg and from the inner reaches of Godthaab Fiord. In East Greenland this land-form more particularly occurs in the interiors of the great fiords; furthermore, mention must be made of the region round Ardencaple Inlet on the western part of Germania Land, while also Vildtland and large tracts on the north-western side of Danmark Fiord are recorded as distinct plateau forms.

The forms of the mountain land are naturally extremely varying in detail, but are essentially referable to two types, the less broken prevailing in the parts which, during the glacial period, were covered by the ice, and the wild alpine type, characteristic of the mountains projecting above the ice. The former type is closely related to the more irregular plateau land and must, in many cases, be considered as belonging to the latter, with valleys so close that the extent of the intermediary areas becomes quite insignificant. The form of the individual mountains may be described as pyramidal or more or less rounded. Whereas the action of the ice may have contributed towards creating the broad outlines of the former, the decomposition and the running water make itself considerably more felt in the modelling of details. As this type is upon the whole difficult of characterization and definition as compared with the other surface forms, it is also difficult or impossible to state the details of its geographical distribution. It must surely be termed the normal surface form of Greenland and is particularly distributed in the following western districts: Upernivik (the Archean rock area) Ritenbenk (eastern part)

Jacobshavn, Christianshaab, the western part of Holsteinsborg, Sukkertoppen (southern part), the greater part of Godthaab, Fiskernæsset, Frederikshaab and large tracts of Julianehaab. In East Greenland this surface form occurs somewhat more scattered, but has nevertheless a very large distribution; in particular mention should be made of the central and outer parts of Franz Joseph Fiord where, however, the rather irregular sedimentary strata produce a still greater variety of forms than is generally found in the Archean areas.

The alpine land-form is the one of all which is most sharply modelled; mountains and valleys often interchange in wild confusion; the mountain sides are generally steep, and the peaks are pointed or comb-shaped (Greenlandic: *Kitdlavât*, i. e. the comb), or quite irregularly dentate or clefted, and as a rule very difficult or impossible of ascent. Still, there are naturally all sorts of transitions between this type and the common mountain form. The alpine country is essentially connected with the gneiss, particularly with the different intrusive rocks, and, as may be expected, it occupies the highest parts, as the reason for its existence must chiefly be looked for in the fact that it was not completely covered by ice during the glacial period. The valleys, which still in many places contain magnificent glaciers were, however, to a still higher degree covered with such within the glacial period, and for this reason they also, as contrasted with the peaks, are more frequently eroded by the ice. The alpine land has its chief distribution in southernmost Greenland, which, viewed from the sea, appears with a highly dentate profile. When passing along the west coast it gradually becomes less pronounced in the direction of the region round Julianehaab, but it reappears in Nunarssuit and the tracts surrounding it. Farther north it appears but rarely, as north of Sukkertoppen and, possibly, on Upernivik Island and the surrounding tracts. When passing up along the east coast, the whole of the long and narrow stretch from Cape Farewell towards Angmagssalik and still farther north seems largely to be of a pronounced alpine character, partly with very great heights; farther north again, special attention attaches to the Liverpool Coast, which has purely alpine forms, but is considerably lower than the other alpine tracts. In this context must further be mentioned a few, quite isolated mountains, which here and there rise to striking heights above their surroundings and, as contrasted with the latter, are of a perfect alpine type; this type includes Kũnait outside Ivigtût, Sadlen and Hjortetakken at Godthaab and the above-mentioned mountains in Melville Bay.

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THE CLIMATE OF GREENLAND

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The meteorology of Greenland is illustrated, in the first place, by observations made at the stations of the Danish Meteorological Institute, the only available observations from those parts extending over a number of years; secondly, by the observations of the various expeditions which have remained for some length of time in the same localities, and finally by the observations of expeditions travelling from one place to another, particularly the three journeys undertaken across the inland ice, *viz.* of Nansen (1889), of Quervain (1912) and of Koch (1913), scientific meteorological results, however, only being at hand from the two former.

As shown by the subsequent tables, the meteorological elements are extremely variable in Greenland, considerable departures from the mean values not being uncommon. Consequently, as an expression of the normal climatic conditions, no great importance should be attached to quite short series of observations as those supplied by the expeditions to certain localities, for even when extending over a number of years, these observations may give rather different mean values, according as a few more or fewer years are included. On the other hand, such observations are, naturally, of interest in the case of places which are far removed from regularly managed stations as, even with the above reservation, they may roughly characterize the differences.

Another peculiarity, which also to some extent will appear from the tables, is the considerable influence exercised on the climatic elements by purely local conditions, seeing that by the topography of the country, with its deeply incised fiords and belts of islands, even stations which are situated in the immediate neighbourhood of each other are in a very unequal degree exposed to important meteorological factors, such as solar radiations and cold sea breezes. Also wind conditions are strongly influenced by local conditions. In summer the sea breeze along the fiords and in autumn the land breeze in the opposite direction are so prevailing and violent as to put obstacles in the way of navigation. Therefore, except in the case of very

exposed places, wind conditions rather supply information about local climatic elements than about the general meteorological conditions dominating the country, to which they are only of secondary importance. The direction of the wind may be determined by the topography of the locality, rather than by the currents within the atmosphere which are the actual cause of the wind.

In proportion to the enormous extent of Greenland the number of meteorological stations is not great. But, though a detailed description of the various local peculiarities must thus be considered to be out of the question, the network of stations is quite sufficient as a basis for a general view of climatic conditions in the greater part of Greenland. (Here we are only thinking of the inhabited coast land; as to the inland ice, see later in this treatise).

In the subjoined tables climatic data are given from most of the stations in Greenland. The observations from Danmark Harbour extend, as is well known, over a period of more than two years; those from North Star Bay are a summary of observations made over a period of a few years from two stations situated at some distance from each other. The remaining observations date from the stations of the Danish Meteorological Institute in Greenland, and all cover periods of a number of years.

The tables are arranged by elements in order to give a general view of the changes from station to station.

The situation of the stations mentioned in the following are:

West Coast

North Star Bay..	lat.	77°	N.	long.	69°	W. (approx.)
Upernivik........	»	72° 47′	N.	»	55° 53′	W.
Jacobshavn......	»	69° 13′	N.	»	50° 55′	W.
Godthaab........	»	64° 11′	N.	»	51° 46′	W.
Qôrnoq..........	»	64° 26′	N.	»	50° 58′	W.
Ivigtût..........	»	61° 12′	N.	»	48° 11′	W.
Nanortalik.......	»	60° 8′	N.	»	45° 11′	W.

East Coast

Angmagssalik....	lat.	65° 37′	N.	long.	37° 16′	W.
Danmark Harbour	»	76° 46′	N.	»	18° 15′	W.
Scoresby Sound..	»	70° 27′	N.	»	26° 19′	W.
Sabine Island....	»	74° 32′	N.	»	18° 49′	W.

The tables show how the common climatic data change according to the latitude, though with the modifications which will be mentioned in detail later on. In spite of its more southern position the summer of Godthaab is

colder than that of Jacobshavn, no doubt owing to its being situated close to the sea and thus more exposed, whereas Jacobshavn is comparatively sheltered. Qôrnoq and Godthaab, which are situated very nearly in the same latitude, the former, however, being far inland at the interior of a fiord, show similar differences as Ivigtût and Nanortalik (continental-oceanic, see below), though in a less pronounced degree. Angmagssalik, which is situated almost in the same latitude as Godthaab, has very nearly the same temperature conditions.

From table II it appears how great are the fluctuations in temperature which may take place from one year to another, particularly in winter. The same is still more strongly expressed in the following tables, III and IV; there positive mean maximum temperatures *may* occur in all the winter months almost as high up as Godthaab, Angmagssalik (table III), and it *may* happen at Upernivik that even the summer months have a negative minimum temperature (table IV).

The most peculiar conditions, perhaps, are shown by table V, with the very high absolute maximum temperatures in winter as against the very low minimum temperature at the same season, not the least characteristic feature being that these maximum temperatures for January and February are even highest at Upernivik. This undoubtedly has some bearing upon the fact that they are caused by a föhn, the intensity of the föhn action being independent of latitude, so that it is a perfect chance where the highest temperature is attained. In summer the absolute maximum temperature seems, to some extent, to increase with the decreasing latitude.

Table VI shows that all stations in the winter months *may* register days without frost, only excepting Upernivik in the months of March and December. South of Ivigtût such days on an average occur every year (the "normal" number of frost days being less than the number of days in the month). In summer Ivigtût is normally free of frost in July, as a rule also in August; Jacobshavn only once in a while has had frost in the month of July, but otherwise frost also normally occurs in the summer months, even though they *may* be free of frost south of Jacobshavn.

Precipitation decreases greatly from south towards north, with the distance from the warm and moist air masses of the Atlantic; the annual amount of precipitation at Godthaab and Angmagssalik is very nearly like that measured on the west coast of Norway, while that of Upernivik and Jacobshavn is as small as that measured within the most continental areas of North Siberia. At all the stations there is a pronounced maximum of precipitation in the autumn months, and less pronounced about May, whereas the amount of precipitation is least in summer and in winter; this annual variation is, however, less pronounced at the two northernmost stations. The precipitation recorded at Danmark Harbour only covers two years, so it cannot be expected to show any regularity. The number of days with

precipitation seems, on an average, to be smallest in summer, except at Upernivik, which only has very few days with precipitation in the months of January, February and April.

The precipitation is of course essentially in the shape of snow; even in July and August snow *may* fall, also at the southern stations, though very rarely. As far north as Godthaab it snows, during these months, on an average once every two to three years.

Everywhere the number of foggy days show the same yearly variation: much fog in summer, little fog in winter. Godthaab and Nanortalik differ distinctly from the other stations by having a considerably greater number of foggy days in summer, owing to their being situated at the open sea.

Table X, which shows the number of stormy days, rather pronouncedly characterizes the winter as the most tempestuous season; Godthaab has a comparatively low percentage of days of calm as compared with the other stations.

The mean atmospheric pressure is rather low and increases with increasing latitude; from table XI the low pressure area which occurs in the winter between Iceland and South Greenland appears clearly from the annual barometric variations at Angmagssalik. The same table also shows the extraordinary variability of the pressure in these regions. Both phenomena recur at the stations of the west coast.

With its great extent from north to south, and being situated, as it is, under the higher latitudes where the solar radiation decreases greatly with increasing latitude, it was *a priori* to be expected that Greenland should contain rather different types of climate. This expectation must be further strengthened by the fact that its most northerly part is situated within the polar area, while its southern end is in the very part of the Atlantic where the drift of the equatorial masses of air towards the polar area takes place through the agency of the large cyclones, thus showing a very considerable positive thermic anomaly. However, the inland ice which covers the whole of the country with the exception of a rather narrow marginal zone, in connection with the cold sea enclosing the country, exercises such a predominant effect as to a very large extent to wipe out the differences; in the north the climate is purely polar, whereas in the south it represents a curious transition stage between the cold climate on the east coast of North America (Labrador) in the same latitude, and the mild oceanic climate of north-western Europe. One of the southern stations of Greenland, for instance, Ivigtût in about lat. 61° N., thus shows a mean temperature of 8° to 10° in the months June to August, $-6\frac{1}{2}°$ to $-7\frac{1}{2}°$ in the months December to February, and negative mean temperatures in all the months

November to April. On the north-western coast of Europe, in the same latitude (Bergen in Norway), no month shows a negative mean temperature, the temperatures of the winter months being a couple of degrees above freezing point and that of the summer months about 11° to 14°. On the east coast of Labrador, on the other hand, in about lat. 58° N. (the station Hebron) the three winter months register about −17° to −21°, the summer months only about 4° to 7½°, while the months October to May all have negative mean temperatures. Fig. I shows the annual variation of temperature for these three stations (plotted from the monthly averages).

The low summer temperature is a direct result of the above-mentioned heat-checking surroundings; in winter the sea is mostly frozen over, and in

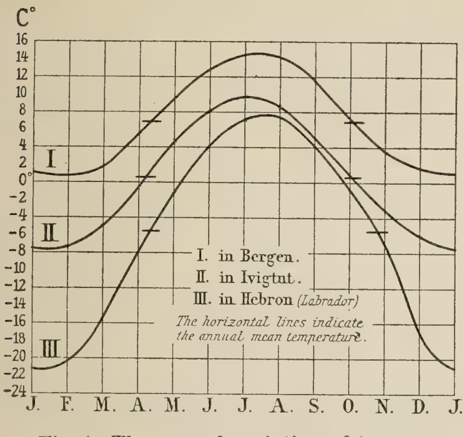

Fig. 1. The annual variation of temperature.

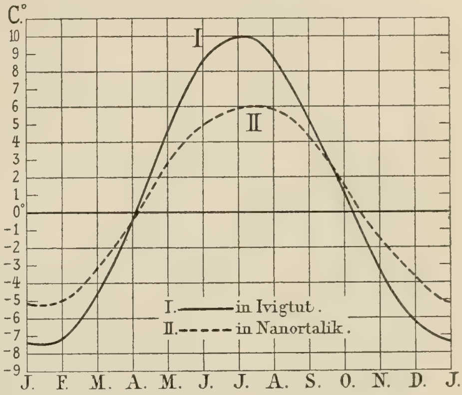

Fig. 2. The annual variation of temperature.

the course of the summer the ice only disappears slowly—its extent from the shore being generally narrowest in August to September (see publications by the Danish Meteorological Institute: "The State of the Ice in the Arctic Seas"), so that also at this time of the year the sea is more or less filled with ice. Therefore, the temperature of the water must keep low all the year round so that the air over it cannot be heated in summer. Thus the heating agency of the sun in summer is limited to the narrow marginal zone, and here, particularly in somewhat enclosed places, rather high temperatures may occur, the average annual absolute maximum at Ivigtût is above 20°, the highest registered temperatures are about 22° to 23°, and the mean maximum temperatures for the summer months about 11° to 14°.

However, owing to the narrowness of the marginal zone, only comparatively small masses of air take part in the heating, and so this high temperature is frequently only of short duration: the faintest breeze carries cooling, and the sea, from which the wind under these conditions is apt to blow, as a sea breeze or monsoon, generally sends cold masses of air with fog in across the land. Consequently, the purely local conditions of a place, and particul-

arly whether it is much exposed to the winds from the sea or well protected against them by lying hidden away by winding fiords or sheltered by mountains, may be of very great importance to its climate: a sheltered position may change it in a continental direction to a degree which is most surprising when considering the short distances from the sea. Therefore, the highest summer temperatures, as well as the lowest winter temperatures occur everywhere within the coast line, at shorter or longer distances from the sea. (It has sometimes caused surprise that the temperature may thus rise when approaching the inland ice; the same, for that matter, also happens in the case of föhns, as their influence on the temperature is frequently weakened at the mouth of the fiord).

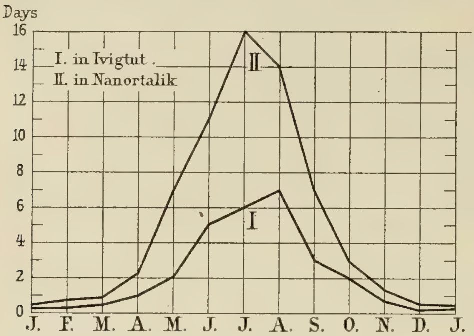

Fig. 3. Number of days with fog.

This is clearly illustrated by the two stations, *Ivigtût* and *Nanortalik.* In fig. 2 the two curves indicate the yearly variation of temperature for the two stations plotted from the monthly averages (I: Ivigtût, II: Nanortalik); they show, in a striking degree, how temperature conditions at Ivigtût are more dependent upon the solar radiation — warmer summer, colder winter — than these of Nanortalik, which has a more oceanic character with a considerably slighter yearly fluctuation. Fig. 3 shows the annual variation in the number of days of fog at the two places (I: Ivigtût, II: Nanortalik). The curves seem to confirm the circumstances mentioned above, *viz.* that the sea breeze carrying fogs and the low summer temperature go together; at Ivigtût, which is warmer in summer, the number of foggy days in the course of the summer months is much less than at Nanortalik.

Fig. 4. Environs of Ivigtût.

The two map sketches, figs. 4 and 5, of the environs of the two stations also confirm the circumstance described above. Ivigtût is situated at the

interior of a winding fiord, in a sheltered position, although the distance to the sea is not great; while, on the other hand, the masses of cold air from the sea have free access to Nanortalik.

In the winter the area of Greenland is, as it were, increased by the formation of ice in the bounding seas, so as to give rise to the strong continental cooling by means of radiation, which is known from the same latitudes in North America and Asia. Its effect is, however, considerably weakened by the frequently rather unstable wind conditions and the masses of warm air carried here by the cyclones. In the isobar-chart for the winter (January) of the North Atlantic it is well known that a pronounced minimum appears between Iceland and the southern point of Greenland (the "Icelandic low"); the latter sends out a considerable trough to the north of Iceland and a smaller one into Baffin Bay. The probable meaning of this mean distribution of pressures is that the large cyclones, wandering across the North Atlantic from America towards Europe, are apt to send troughs (part minima) into Baffin Bay or Denmark Strait, possibly also themselves on occasion following these courses. Nor does it seem unreasonable that a plateau of 2000 to 3000 metres should exercise a decisive effect on the development of the cyclones touching it, not least after the more recent theories on their mechanism, according to which they are the result of the interaction of the polar and equatorial masses of air at the line where their surface of discontinuity cuts the ground (the polar front). This warmer air is carried to the areas east as well as west of Greenland, which not only makes the winter milder, but not infrequently interrupts the frost for a short period, particularly in the southern part.

Fig. 5. Environs of Nanortalik.

For that matter, the cyclones may also bring about rises of temperature along the coasts of Greenland in quite a different, though more indirect manner, and entirely independent of the origin of their masses of air, *viz.* by causing föhn winds. For the formation of such there is ample opportunity in the numerous fiords which flow into the sea from the elevated masses of the interior; however, pressure conditions of quite a special nature are required in order that the masses of air passing out from the interior may follow the slope of the land and become a dynamically heated, descending wind, a distribution of pressures which may be caused by the cyclones. The föhn heat is distinguished from the first mentioned mild weather by the

dry air accompanying it, while the ordinary cyclone-thaw (or a lower degree of frost) generally goes with moist weather and precipitation.

Therefore, in the winter months the above-mentioned high maximum temperatures frequently occur. It is not uncommon that they become rather high, 5° to 10°, and occasionally 12° to 15° in December to February.

The immense extent of these "warm waves" in winter appears most clearly from a few examples. November and December, 1878, are among the mildest occurring within the period during which regular observations have been made in those parts, and this applies to all stations. Upernivik, Jacobshavn, Godthaab and Ivigtût registered the following mean temperatures (taken in succession): November about —2.0°, —1.1°, —1.3°, —2.3°; December —3.7°, —2.6°, —0.8°, 2.1°. The mean maximum temperatures were in the same order of succession (there is no record of Upernivik for November): November +2.6°, +3.6°, +5.2°; December —0.1°, +1.6°, +2.0°, +4.8°. The mean minimum temperatures (exclusive of Upernivik for November) were: November —4.3°, —1.6°, —0.6°; December —7.6°, —5.5°, —3.4°, —0.7°. Precipitation in the course of these months: November 53, 48, 209 and 342 mm, December 24, 32, 82 and 290 mm. A comparison with the tables given below shows how exceptionally warm these two months were: the latter figures — the precipitation — give a hint as to the cause of the mild weather: the high amount of precipitation, particularly in the southern part, suggests a powerful cyclonic action with a continuous flow, in a northern direction, of masses of air from more southern parts of the Atlantic.

Similar very mild periods over the whole of Greenland, but of very short duration, occur not infrequently; and now it is possible to form an estimate of simultaneous weather conditions, particularly by means of ship observations in the Atlantic. A typical example of this occurred during the latter part of January, 1925. After a long period of the usual cold weather everywhere, 20° to 30° of frost at the northern and 5° to 15° at the southern stations, the temperature suddenly rose to above freezing point, at Ivigtût on the 23th, at Godthaab on the 24th, at Jacobshavn on the 25th, while the freezing point was almost attained on the 26th at Upernivik. The highest temperatures reached are 5.4°, 8.2° 8°, and —0.4° respectively. The wind directions with which these rises of temperature set in are south-east, chiefly east, though somewhat variable, and at Upernivik south; the velocity is everywhere considerable, 10—15 m/sec. This might tempt one to the supposition that as far as the first three stations were concerned, the wind was of a föhn nature; that this, however, is not the case, appears from the fact that the rise of temperature is everywhere accompanied by a greater or smaller amount of precipitation, at Ivigtût during the whole of the mild period, at Godthaab and Jacobshavn, particularly towards its termination, at Upernivik, where the rise of temperature was only of quite short duration, it was accompanied by snow. The pressure was low at all stations, and

according to the weather charts of the North Atlantic which are published daily by Deutsche Seewarte, the weather conditions there were, at the same time, dominated by an immense "low". On the 24th the pressure to the east of Newfoundland was as low as 730 mm, and the thought naturally presents itself that the latter continued as far as Baffin Bay and Davis Strait, and that the rise of temperature in Greenland was due to the masses of warm air from the Atlantic which, by the anterior part of the cyclone, had been carried so far north. The rainfall may then either have been cyclonic rain or orographic rain over the rapidly rising coast land.

At Angmagssalik, on the east side, the rise of temperature began in the evening of the 23th, and the maximum was reached on the 25th with 4.5°. Also here the wind was rather strong from the east, and accompanied by precipitation, all of which corresponds with the situation of Angmagssalik on the north-eastern side of the large "low."

As the south point of Greenland extends over part of the large area of low pressure, which, particularly on the 25th, seems to have formed one large cyclone, dominating the whole of the Northern Atlantic from Newfoundland to Ireland and from Greenland to the Azores, it might be imagined that similar conditions would come to prevail in the southern part of Greenland as those which sometimes occur in the föhn areas of the Alps, *viz.* that the air flows right across the plateau, condensing its moisture on the windward side, while the air thus desiccated, when descending on the other side, is dynamically heated to a föhn wind. Such cases of a "total föhn" have been described by Quervain as occurring during his passage across the inland ice in the summer of 1912. That this was not so in the case we are here dealing with appears from the amount of precipitation at the stations along the west coast.

The duration of the föhn wind varies greatly. It may last for several days and nights, but then again it may be quite transitory; it may blow very irregularly, partly in violent gusts, and its peculiar character, dryness and a comparatively high temperature, may be subject to great fluctuations. Also its range may differ; the föhn at Jacobshavn may sometimes be felt as such all the way to Godhavn on Disko, but not always. The subjoined table contains observations of temperature and wind during a föhn at Jakobshavn. The velocity of the wind is indicated to a scale of 0—12; the maximum temperature, which is read every morning at 8 o'clock, and which has thus occurred in the course of the preceding twenty-four hours, is noted on the date preceding the day on which the reading takes place.

1919	8 a.m.	2 p.m.	9 p.m.	Max.	8 a.m.	2 p.m.	9 p.m.
Jan. 30	−20.7°	−17.9°	−15.5°	−1.3°	N 1	N 1	Calm
31	−1.3	−1.1	−1.3	−5.1	E 5	E 4	ENE 6

1919		8 a.m.	2 p.m.	9 p.m.	Max.	8 a.m.	2 p.m.	9 p.m.
Feb.	1	3.7	5.4	5.1	6.7	E 7	E 7	E 5
	2	0.7	1.3	−4.9	1.9	E 4	E 4	Calm
	3	−6.1	−3.9	−4.7	−2.3	ENE 1	E 3	E 1
	4	−12.5	−13.1	−17.1	−11.3	E 1	SSW 1	ESE 1
	5	−17.3	−17.1	−20.1	−15.3	WSW 3	WSW 2	ESE 1

With the sudden intense wind from the east the temperature rises violently, 15° to 20°, and then keeps near freezing point with slight fluctuations in both directions, until on the evening of the 2nd wind conditions become more unstable, evidently as a result of the fact that the distribution of pressure, which makes the masses of air flow down along the sloping plateau, is on the point of shifting; with changing and faint breezes a severe frost then again sets in.

The curve on fig. 6 shows a thermogram from Upernivik, taken during a föhn in January, 1923. On the curve the common hours of observation, 8 a.m., 2 p.m. and 9 p.m., are marked, and against these marks are recorded the winds observed at the hour in question (o = Calm). The curve clearly shows the same facts as those shown by the table above, as well as the rather fluctuating temperatures, these fluctuations being greatest when the temperature is rising. Owing to the slow action of the thermograph, the irregularities really occurring have undoubtedly been greater than indicated by the curve.

It happens not infrequently that pronounced föhn periods occur simultaneously at most stations, even though they may be more or less intense in the different places. Thus at the time of the föhn mentioned above from Jacobshavn, there was also a föhn at Upernivik (maximum temperature −0.7° on the 2nd) and at Godthaab (maximum temperature 10.2° on the 1st). Then there is generally a comparatively low pressure so that a cyclonal action must be supposed to be going on over the sea. However, the peculiar coastal conditions with great heights in the immediate background, as already suggested, very frequently cause the winds arising in the coast area not to fit into the field of isobars belonging to the cyclone, as according to the baric wind law (In Medd. o. Gr. LX it is, for instance, mentioned that there is frequently, with certain winds over Disko Bay, calm at Godhavn on Disko and at Jacobshavn, whereas the sea is set into violent motion by strong winds). The winds which blow at the stations along the coast must, therefore, frequently be supposed to originate in purely local pressure fields, caused by the congesting or sucking action of the proper cyclonic air current along or over the coast area. When a cyclone occurs in the sea to the west of Greenland, it may consequently, according to circumstances, cause föhns or overflow the coast with masses of air from the sea. In winter the result will, in both cases, be a strong rise of temperature; the difference appears from weather conditions generally, the föhn having its peculiar character, resulting from its dryness,

while the sea air is humid and frequently causes precipitation. Simultaneously with the föhn illustrated by the curve below there was thus mild weather also at the more southerly stations, at Ivigtût further accompanied by precipitation, which proves that it could not have been a föhn.

From the expedition to Danmark Harbour A. Wegener described a special kind of cloud, which frequently occurred together with föhns (Medd. o. Gr. XVII). He is of the opinion that they have been generated in a similar manner as trade wind clouds over mountains ("Hinderniss Wolken"). The inequalities of the coastal area must be supposed to lend a wavy motion to the passage of the föhn, like that of a rivulet along a stony bed. Over elevated parts the air masses are pressed upwards in a wave, and when the air contains

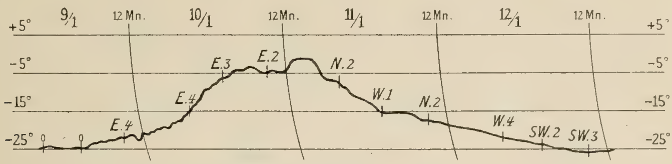

Fig. 6. Föhn in Upernivik. January, 1923.

sufficient vapour, condensation may take place, this condensation appearing in the shape of a cloud which remains stationary over the said elevation. If smaller clouds are detached and carried along by the wind they dissolve quickly.

The inland ice, as is well known, forms a continuous sheet of ice and snow, in summer only leaving bare the said marginal zone which, in the places where it is broadest, has a width of about 150 kilometres. The whole of the remaining country forms a plateau, which is constantly covered with ice, and which rises gradually from the coast towards the interior up to heights of 2000 to 3000 metres. The expedition of Nansen, which crossed it in latitude 64° to 65° N. measured, as their greatest height, about 2700 metres, that of Quervain, which passed from the north-west towards the south-east in latitudes from 70° to 66° N., measured about 2500 metres. Both expeditions took place in summer, August to September and June to July, from which time of the year the meteorological observations date.

The observations of temperature from both expeditions, roughly speaking, show the same picture, though there are considerable differences as regards details. The temperature naturally decreases from the coastal areas in the direction of the interior, but in a rather striking manner. The process is most regular, as found by the expedition of Quervain, which covered the longest distance and extended farthest north. It falls into three very sharply divided sections: the first 180 kilometres, up to a height of 1900 metres, where the diurnal average, with small fluctuations, was about $-1°$; then the temperature suddenly declined, and for the following 280 kilometres,

again with small fluctuations, remained about $-10°$; finally, after the highest point had been passed, from a height of 2250 metres it again rose to about $0°$, where it remained throughout the last 170 kilometres, until the fiord area was reached once more. Quervain gives the following explanation of this phenomenon: the wind systems of the surrounding seas extend across the inland ice and make themselves felt in the two mild zones, whereas the cold central area in a much lesser degree is subject to such disturbances in the atmosphere that a more intensive cooling can take place through nightly radiation, which is in accordance with the fact that he there found more stable wind conditions.

During the passage of Nansen the same differences occur, though less sharply distinguished. From the time of the ascent of the inland ice, up to about 100 km in a bee line from the east coast, the temperature falls gradually from $0°$ to about $-10°$, and this temperature is retained, with greater or smaller fluctuations, until the highest point is reached at a distance of about 170 km from the coast. Then the temperature over the following 50 km further falls to about $-30°$, and here it remains with small fluctuations, for the following 60 km then rising gradually, though with a few considerable fluctuations, over the last 170 km. In both cases the coldest area is thus to be found very nearly in the centre of the country, but whereas on the expedition farthest north it was found to comprise the greatest heights, it lay, on the route of Nansen, decidedly on the western slope, though the decline is very slight in the highest levels.

Wind conditions show very great regularity, it having been observed by all that the winds chiefly blow from the highest levels towards the two coasts, though with directions corresponding with a deflection resulting from the rotation of the earth, *viz.* north-westerly on the east side and south-easterly on the west side. These winds, which thus give the impression of a flow of air from the interior down the slopes towards the coast, are said to blow with a surprising steadiness and regularity. Still, Quervain, as already suggested, found calmer wind conditions within the cold central area, which further contains the divide of the winds, and this also seems to appear from the observations of Nansen, though the wind directions given by him show that the divide of the winds has been passed.

That these currents of air are not the only ones occurring, we have, however, indisputable evidence; both expeditions occasionally had wind conditions which were clearly the result of the common distribution of pressure over the sea round Greenland, and after the highest point had been passed, Nansen himself witnessed the passing of a small cyclone, with a sharply falling barometer, snowstorm and a sudden shifting of the wind from south-east to west-north-west.

Over the interior of the inland ice there are partly very low temperatures, on the most northerly route about $-10°$ (average) with the individual

observations fluctuating between about $-5°$ and $-22°$, on the southerly $-30°$, fluctuating between about $-20°$ and $-45°$ (the lowest figures, however, representing night temperatures derived by extrapolation by means of the common form of the diurnal temperature variation). These temperatures must be the result of the cooling action of the snow, its temperature falling sharply in the course of the night, while in the day it at most reaches $0°$. This circumstance is further expressed by the great difference experienced by the two expeditions between the temperatures of the central area, *viz.* $-10°$ and $-30°$, in that the northerly expedition took place at the time of the highest altitude of the sun, partly in midnight sun, whereas the southerly expedition took place shortly before equinox, so that the nightly radiation might come to exercise a much greater influence and the diurnal insolation a corresponding slighter one. On the other hand, the temperatures are essentially the same over the marginal zones where sea breezes still make themselves felt (see above), and this corresponds with the fact that the temperatures at the coast stations (see table I) do not vary much within the period in question (June—September).

As compared with the temperature which, in consequence of the normal vertical fall of temperature, must be expected to prevail in the same altitude of the free atmosphere, the temperatures registered are lower, particularly those from the southern route. At an altitude of 2500 metres and with a fall of temperature of $\frac{1}{2}°$ per 100 metres, the temperature may be computed at about $7°-12.5° = -5.5°$ as against $-10°$ for the journey of Quervain, and about $4°-12.5° = -8.5°$ as against $-30°$ for the journey of Nansen (see tableI). Quervain has computed the actual temperature gradient from all observations taken on the inland ice, and at Jacobshavn or a station situated immediately at the margin of the ice. Under favourable radiation conditions he found very large gradients, partly above $1°$ per 100 metres (particularly by comparison with the ice margin), whereas in overcast weather or, in other words, when radiation was slight, there was only a small gradient, *viz.* $0.3°-0.4°$. The distribution of temperature upwards along the inland ice is thus, under favourable radiation conditions, decidedly dynamically unstable (the adiabatic gradient being slightly under $1°$). Under such conditions the outflow of the air in the direction of the coast is to be expected. This may even be further intensified by the actual transition from the ice to the ice-free area, where the earth's surface may be strongly heated. Thus Quervain, by comparing observations from a station slightly outside the ice, was occasionally able to record such a large gradient that the state was statically unstable; the masses of air over the more elevated portions of the ice are absolutely heavier than those outside the margin of the ice and must consequently, without other influence, "rush down" as corresponding with the prevailing south-east wind.

Directly, by means of observations, it has thus been sufficiently proved

that the inland ice, as had been imagined, by its cooling action causes a general outflow of air in the direction of the coasts, and this air current represents the prevailing motion of the wind over the inland ice which is otherwise well known from various expeditions.

For a long time attempts have been made to connect these wind conditions with the existence of an anticyclone over the inland ice, which must be taken to signify that the pressure is here everywhere higher than at the same altitude over the sea. This agrees with the steadiness of the flow across the inland ice towards the coast, the downward movement of which most frequently ceases at the marginal zone. Only with quite special pressures (see above) does this air current pass farther down the coast slopes, at the foot of which a föhn is then blowing. By means of his aerological observations from Danmark Harbour Wegener was able to prove directly how the föhn current might vary as regards altitude, now reaching the ground and now blowing at higher levels.

On the other hand, it is more difficult to form any definite idea of the actual formation of such an anticyclone. The great winter anticyclones, for instance, the Siberian anticyclones, are conceived more or less as a result of the cooling of stagnant air, which gradually causes the masses of air to subside. Over the inland ice this is not the case, there being a very pronounced outflow of the cooled air. It might be natural to make a comparison of these conditions with those accompanying the winter monsoons over the coast areas of the large continents; but these wind systems are attended by a counter current in the high levels, in West Greenland thus from directions about north-west, in East Greenland about south-east, and now the observations of Quervain in West Greenland and those of Wegener in Danmark Harbour show that the "winds of outflow" in both places remain as the prevailing direction of the wind, also in the higher altitude, though shifting somewhat to south and north respectively, which suggest that the anticyclone, as such, extends into the high levels.

Ideas have been entertained of the possibility of the existence of a "polar whirl," *viz.* an area round the Pole where the masses of air suck together and, while flowing southwards in the lower strata and being strongly deflected westwards by the rotation of the earth, tend dynamically to maintain a high pressure within themselves, in the same manner as the brave western winds bound the high pressure area of the southern tropics towards the south. According to recent theories of cyclones these are the result of the interaction between the masses of cold air from this polar whirl and the masses of warm, moist air from the western and south-western currents from more southerly latitudes. If one adopts this hypothesis, one may imagine northern Greenland to be lying as an obstacle against this ring of whirls, interrupting the regular east to west current. The result must then be an outflow of the masses of cold air contained

within it, or an extension of the high pressure area in a downward direction over Greenland, bounded on the east side by northern winds and on the west side by southern winds or, in other words, exactly as conditions have been found to be. This also agrees well with the fact that when the systems of cyclones extend over the ice, this only seems to take part over the southern part (see, for instance, the numerous maps accompanying Quervain's treatise on the expedition 1912—13). Over northern Greenland the high pressure remains stationary and keeps up the communication towards the north.

TABLE I

Mean temperature for the months and the year.

	January	February	March	April	May	June	July	August	September	October	November	December	the year
North Star Bay	−29.2	−29.4	−26.2	−17.3	−5.0	−1.5	−4.7	−3.8	−2.2	−10.0	−18.0	−25.2	−12.7
Upernivik......	−22.0	−22.8	−22.0	−14.6	−4.2	1.7	5.0	4.9	0.5	−4.1	−9.9	−17.0	−8.7
Jacobshavn	−17.7	−19.0	−16.8	−9.8	−0.5	4.8	7.7	6.4	1.6	−3.7	−8.7	−12.9	−5.7
Godthaab......	−9.8	−10.0	−7.8	−3.9	0.7	4.5	6.6	6.3	3.2	−0.9	−4.6	−8.1	−2.0
Qôrnoq.........	−10.8	−10.7	−8.3	−3.8	2.1	6.4	8.4	7.6	3.3	−1.3	−5.2	−8.9	−1.8
Ivigtût.........	−7.6	−7.3	−4.9	−0.5	4.5	8.0	9.7	8.4	4.9	1.0	−3.0	−6.0	0.6
Nanortalik	−5.1	−5.0	−3.1	−0.8	2.9	5.0	5.9	5.9	4.2	1.5	−1.6	−3.6	0.5
Angmagssalik ..	−8.5	−10.4	−8.1	−4.5	0.8	4.9	6.6	5.9	3.3	−1.3	−5.4	−7.2	−2.0
Danmarkshavn	−21.9	−27.4	−22.4	−19.5	−7.3	1.1	4.4	2.2	−4.0	−14.4	−20.4	−20.9	—

TABLE II

Highest and lowest monthly mean temperature.

	January	February	March	April	May	June	July	August	September	October	November	December	the year
Upernivik......	−13.4	−11.4	−12.6	−5.8	−1.6	4.4	8.8	8.7	3.3	−0.2	−5.5	−3.6	
	−27.6	−30.8	−28.3	−20.0	−9.4	−0.7	3.3	2.5	−1.5	−7.5	−14.8	−25.2	
Jacobshavn	−7.9	−5.1	−7.6	−1.0	3.4	7.9	11.1	10.3	4.9	0.5	−1.1	−2.5	
	−26.3	−29.4	−24.8	−16.3	−5.0	2.0	6.1	4.9	−0.6	−9.6	−12.1	−22.1	
Godthaab......	−2.5	1.0	−1.5	0.8	2.6	7.4	9.2	8.5	6.1	2.9	1.4	−0.6	
	−15.0	−16.7	−13.7	−8.3	−0.6	2.7	5.4	4.3	1.5	−3.4	−6.9	−12.4	
Ivigtût.........	−1.3	4.0	0.9	5.3	7.1	11.1	11.7	10.6	7.8	4.9	2.3	2.0	
	−11.2	−13.8	−11.4	−4.6	2.2	6.1	8.2	6.5	3.9	−1.6	−5.9	−11.5	
Angmagssalik...	−2.5	−4.6	−4.8	−1.2	3.4	7.1	8.5	7.7	5.1	2.9	−1.4	−1.7	
	−14.8	−16.9	−13.0	−8.2	−1.6	3.4	5.7	4.5	1.2	−5.5	−8.7	−13.7	

TABLE III

Highest and lowest value of monthly mean maximum temperature.

	January	February	March	April	May	June	July	August	September	October	November	December	the year
Upernivik......	−8.4	−6.4	−6.5	−1.9	1.9	8.6	12.4	12.4	6.2	4.8	−4.2	−0.1	
	−24.8	−28.0	−23.5	−14.8	−3.7	1.9	6.0	5.7	0.6	−5.6	−11.9	−20.0	
Jacobshavn.....	−4.2	−0.5	−3.7	2.1	5.8	11.8	14.6	13.1	8.3	2.2	2.6	1.6	
	−22.6	−25.0	−16.8	−9.3	0.0	4.8	9.4	7.9	2.5	−5.3	−8.3	−18.0	
Godthaab......	−0.3	3.5	1.3	5.5	8.2	11.4	15.6	13.7	8.9	4.5	3.6	2.0	
	−12.7	−13.2	−11.0	−5.5	2.4	5.2	9.1	6.9	3.6	−1.8	−4.7	−11.7	
Ivigtût.........	1.3	7.3	4.9	9.0	11.1	15.5	15.9	14.5	11.2	8.0	5.2	4.8	
	−7.5	−10.4	−7.2	−0.9	5.6	9.3	11.9	9.6	6.6	1.3	−2.8	−7.7	
Angmagssalik...	0.2	0.1	0.3	6.1	8.9	13.7	14.6	13.8	9.7	5.5	0.8	0.5	
	−10.5	−11.0	−7.0	−2.1	4.5	8.6	10.6	9.5	5.2	−2.2	−6.1	−9.9	

TABLE IV

Highest and lowest value of monthly mean minimum temperature.

	January	February	March	April	May	June	July	August	September	October	November	December	the year
Upernivik......	−16.2	−15.3	−17.0	−10.5	−4.5	1.3	5.4	5.6	0.5	−2.7	−8.1	−7.6	
	−30.3	−33.0	−31.9	−24.6	−11.5	−3.3	−0.5	−0.3	−4.4	−10.2	−16.5	−27.2	
Jacobshavn.....	−11.7	−8.8	−11.4	−5.5	0.9	4.5	7.0	5.9	1.8	−2.7	−4.3	−5.5	
	−30.7	−33.0	−29.4	−22.4	−10.0	−0.7	3.1	1.6	−4.7	−12.0	−15.8	−25.4	
Godthaab......	−4.9	−0.6	−3.3	−2.2	−0.2	3.8	5.4	5.0	2.9	1.3	−1.6	−3.4	
	−17.4	−19.9	−17.1	−11.9	−4.2	−0.4	1.5	1.2	−1.0	−6.5	−10.1	−16.3	
Ivigtût.........	−3.9	−0.1	−3.6	1.4	2.4	5.7	6.9	6.7	4.4	1.3	−0.6	−0.7	
	−16.4	−19.1	−17.8	−9.7	−1.8	2.0	4.1	2.7	0.3	−4.9	−9.4	−14.5	
Angmagssalik...	−5.6	−8.5	−8.4	−5.2	0.6	3.5	4.0	4.2	2.2	0.2	−3.8	−4.4	
	−17.7	−20.0	−16.1	−13.4	−6.3	−0.7	1.1	0.8	−2.2	−8.2	−12.0	−18.1	

TABLE V

Absolute highest and lowest temperature.

	January	February	March	April	May	June	July	August	September	October	November	December	the year
Upernivik......	12.8	15.6	8.2	10.0	13.2	16.5	19.8	20.8	20.3	17.3	11.7	8.7	
	−39.2	−42.3	−40.6	−34.2	−21.1	−8.9	−7.2	−4.2	−10.4	−17.9	−26.7	−35.9	
Jacobshavn.....	9.5	9.5	8.9	12.7	15.0	19.4	21.9	18.5	17.0	14.4	10.3	11.1	
	−42.7	−43.2	−41.3	−37.0	−20.5	−6.0	−0.3	−4.5	−13.1	−20.2	−27.7	−36.5	
Godthaab......	11.0	10.7	11.5	13.2	16.0	23.2	24.2	21.4	16.7	11.2	14.2	15.0	
	−28.9	−27.5	−28.2	−21.1	−11.5	−3.9	−1.1	−2.4	−7.8	−14.6	−18.6	−25.6	
Ivigtût.........	13.3	14.5	14.2	16.3	23.1	23.0	23.4	20.6	21.2	18.2	15.4	14.2	
	−27.7	−28.9	−27.1	−19.6	−10.5	−2.2	0.3	−1.4	−8.7	−12.8	−18.0	−26.5	
Angmagssalik...	8.9	15.2	11.1	14.1	16.2	25.3	24.8	25.2	21.2	13.4	12.7	8.2	
	−30.3	−30.7	−28.4	−25.4	−15.7	−5.6	−3.0	−5.7	−7.6	−13.6	−25.2	−29.4	

TABLE VI

Mean of days of frost and highest and lowest number.

	January	February	March	April	May	June	July	August	September	October	November	December	the year
Upernivik......	31	28	31	30	30	22	5	4	21	29	30	31	
highest........	31	28(29)	31	30	31	30	18	20	30	31	30	31	
lowest.........	29	27	31	28	27	8	0	0	10	24	29	31	
Jacobshavn.....	31	28	31	30	26	6	0.03	2	18	28	29	30	
highest........	31	28(29)	31	30	31	20	1	11	29	31	30	31	
lowest.........	29	27	29	26	16	0	0	0	5	18	25	26	
Godthaab.......	31	28	30	28	22	7	0.8	1	10	25	29	30	
highest........	31	28(29)	31	30	30	19	7	11	23	31	30	31	
lowest.........	24	16	25	21	13	0	0	0	0	4	16	24	
Ivigtût.........	30	27	29	25	13	0.8	0	0.1	6	21	27	29	
highest........	31	28(29)	31	30	26	7	0	2	12	30	30	31	
lowest.........	23	16	24	11	3	0	0	0	0	11	16	16	
Angmagssalik...	30	28	30	29	23	11	4	5	15	26	29	30	
highest........	31	28(29)	31	30	30	19	12	12	28	31	30	31	
lowest.........	24	26	26	22	9	2	0	0	5	14	24	25	

TABLE VII

Mean precipitation, mm.

	January	February	March	April	May	June	July	August	September	October	November	December	the year
Upernivik......	13	16	21	14	15	12	22	28	26	27	25	14	233
Jacobshavn.....	8	7	12	9	14	20	29	32	34	22	17	11	215
Godthaab......	44	53	51	36	52	37	64	79	87	66	50	49	668
Ivigtût.........	89	70	91	61	109	80	83	89	150	143	112	90	1167
Angmagssalik...	89	43	53	64	73	52	52	63	108	154	86	70	949
Danmarkshavn.	30	17	18	3	4	6	1	8	7	7	26	19	146

TABLE VIII

Number of days with precipitation (mean).

	January	February	March	April	May	June	July	August	September	October	November	December	the year
Upernivik......	5	5	7	5	8	7	8	9	11	13	11	7	
Jacobshavn......	9	8	10	8	9	7	9	9	11	11	12	10	
Godthaab......	16	14	16	13	12	10	11	13	14	14	14	14	
Ivigtût.........	13	11	13	11	11	10	10	10	15	13	12	12	
Angmagssalik...	17	14	16	15	15	12	10	10	16	16	16	19	

TABLE IX

Number of days with fog (mean).

	January	February	March	April	May	June	July	August	September	October	November	December	the year
Upernivik......	2	2	2	5	5	10	11	6	2	1	1	2	
Godthaab......	0.2	1	1	3	6	11	13	13	6	2	1	1	
Ivigtût.........	0.3	0.3	1	1	2	5	6	7	3	2	1	0.2	
Nanortalik......	0.4	1	1	2	7	11	16	14	7	3	1	1	
Angmagssalik...	1	1	1	3	7	9	8	7	4	3	2	0.4	

TABLE X

Number of days (mean) with storm in each month as well as the percentage of observations of calm in the year.

	January	February	March	April	May	June	July	August	September	October	November	December	Calm %
Upernivik.......	0.3	0.3	0.7	0.1	0.1	0.2	0.3	0.6	0.4	0.6	0.4	0.4	c. 30
Jacobshavn.....	1	0.9	0.8	0.3	0.7	0.7	0.5	0.8	1	1	1	1.5	35
Godthaab......	0.7	1	0.9	0.8	0.6	0.3	0.3	0.5	1	1	0.9	1	14
Ivigtût...........	0.6	0.3	0.4	0.2	0.2	0.2	0.1	0.1	0.2	0.2	0.2	0.4	50
Angmagssalik...	1	1	1	0.4	0.1	0.06	0	0.3	0.2	0.3	0	0.5	51

Mean atmospheric pressure for the whole of the year (reduced to 0° C and 45° lat.).

Upernivik 758 mm, *Jacobshavn* 757 mm, *Godthaab* 755 mm, *Ivigtût* 755 mm, *Angmagssalik* 756 mm.

The heights of the stations above the sea are: 12 m, 13 m, 11 m, 5 m, and 20 m respectively.

Thunder has not been experienced at Upernivik; at Jacobshavn it is said to have occurred a few times (since 1864); at the stations farther south thunder is not so rare. At Nanortalik within a period of about 30 years thunder has occurred on the following days in each month

9	7	5	2	0	2	6	9	6	1	1	4

which averages 1 to 2 thunder days in the year.

Mean temperature for individual months from the observations of the expedition during the stay at the station:

SCORESBY SOUND

Year 1891—92. (Ryder.)

−18.5	−24.3	−25.5	−17.1	−5.1	1.1	4.4	(3.5)	−1.5	−7.0	−20.2	−20.3

SABINE ISLAND

Year 1869—70 (Koldewey).

−24.1	−23.8	−23.3	−16.5	−5.4	2.3	3.8	0.7	−4.3	−13.8	−18.3	−17.1

TABLE XI
ANGMAGSSALIK

	January	February	March	April	May	June	July	August	September	October	November	December	the year
Mean pressure 700 mm +	48.6	52.4	55.6	57.6	61.6	60.3	59.0	59.6	55.8	54.8	52.7	49.6	55.7
highest mean 700 mm +	62.3	69.1	68.8	66.5	68.2	67.8	64.5	63.8	61.1	64.8	60.9	61.6	58.6
lowest mean 700 mm +	41.1	41.2	43.7	46.1	56.7	54.2	54.4	53.9	50.6	48.1	43.3	39.1	52.4
highest observation 700 mm +	89.4	88.5	83.8	81.7	83.7	79.4	74.1	72.5	78.0	86.0	79.1	86.2	—
lowest observation 700 mm +	7.6	13.2	21.4	17.3	36.6	33.7	39.2	39.5	25.8	21.1	18.4	11.0	—
relative humidity..........	83 %	82 %	80 %	78 %	77 %	74 %	72 %	72 %	73 %	79 %	80 %	81 %	78 %
mean wind velocity scale 0—6	0.9	0.7	0.7	0.6	0.5	0.5	0.6	0.5	0.6	0.6	0.7	0.8	0.6
mean amount of clouds.........	69 %	62 %	61 %	64 %	68 %	63 %	56 %	55 %	65 %	69 %	68 %	68 %	64 %

THE FLORA OF GREENLAND

BY

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I. INTRODUCTION

The latest known part of the Greenland flora is that of the northern region, which is quite natural, as this is the least accessible part of the immense country. Thanks to the expeditions which of late have been sent there, rather considerable collections have been brought home from the districts north of lat. 76° N., and, further, many other parts of the country have during later years been made subject to closer botanical investigations.

Consequently, I think that one is entitled to say that the floristic part of the research of the vegetation of Greenland has reached its natural conclusion.

This, however, only applies to the so-called higher plants, *viz.* phanerogams and pteridophytes, of which considerable new finds are hardly to be expected in the future. Conditions are otherwise as regards the cryptogams (exclusive of the pteridophytes) of whose occurrence only insufficient knowledge is at hand, and this in spite of comparatively many and comprehensive works on the subject. The approximate number of species for each of these groups is: 600 bryophytes, 300 lichens, 185 marine algæ, 375 freshwater algæ, 600 diatoms (marine and freshwater) and 45 dinoflagellates (marine and freshwater), but especially for the microscopical forms—and they constitute the majority—such figures are quite unreliable, being at any rate mere minimum figures.

Any attempt at making phyto-geographical studies based upon the whole of the flora will, therefore, be in vain, and we must rest content with phanerogams and pteridophytes which, as the most conspicuous, are also gathered by non-professional collectors.

Further, the distribution of the plants within each of the parts of this extensive country is now presumably rather thoroughly investigated, and in the same manner as no considerable increase of the number of species

can be expected for the whole of Greenland, there is no reason to expect great changes in our knowledge of the distribution of the species within the individual parts.

In accordance with the delimitation of species applied by me, the *number of species of phanerogams and pteridophytes for the whole of Greenland amounts to 390*[1]. This is no great number when considering the size of the country, but it should be borne in mind that the whole of the interior of Greenland is covered by ice, and that the climate is unfavourable to vegetation, both on account of the northerly position of the country and on account of the huge reservoir of cold, constituted by the inland ice, and, finally, on account of the encircling cold sea-currents. These three circumstances also contribute towards the comparatively small difference in the vegetation of the north coast of Greenland and that of its south point, a distance of more than twenty-three and a half degrees of latitude. No less than 32 (8.2 per cent.) of the 390 species extend from the north coast to Cape Farewell, which circumstance in itself is rather unique, and then these 32 species make about half (42 per cent.) of the whole of the sparse flora (77 species) of the north coast.

Nevertheless, there is naturally a much richer flora in the most southerly part of Greenland with its tall birch copses than on the bleak north coast facing the ever ice-covered Polar Sea, the most northerly vegetation known. With a view to the study of the flora and its distribution it is, therefore, natural to attempt to divide the country, or rather the coasts, into smaller areas or districts, and this has also been done by the former investigators, as for instance by E. Warming, A. G. Nathorst and M. P. Porsild.

II. THE AGE OF THE FLORA IN RELATION TO THE GLACIAL PERIOD

As to the *age of the Greenland flora* this question cannot be answered with any certainty. In the Cretaceous and older Tertiary periods Greenland had a warmly temperate flora, the remains of which are known, *inter alia*, from deposits in central West Greenland (the Vaigat District), this flora being now naturally extinct in Greenland. In arctic and sub-arctic to temperate regions there is, at the present time, a flora whose species for the greater part have a circumpolar distribution. It is a natural supposition that this flora in pre-glacial times lived in the Polar regions and was gradually driven south, according as the ice gained the upper hand. The question which interests us in this context is whether the most hardy of the species of this flora, *viz.* those which at the present time live in the most northerly

[1] The few species brought in by man during the last two centuries have not been included in that figure.

plant-bearing regions may have survived the maximum of the glacial period in Greenland. I do not mean that they have continued to exist in the same area since before the glacial period, but for instance, that by the action of the ice they were driven down to southern Greenland, and from there, at a later period, again migrated towards the north. This question must, I think, be answered in the affirmative, and this I base chiefly on the records of "higher" plants from the present "nunataq" areas. There is every probability that even during the maximum extension of the inland ice there were nunataqs, rocky walls, ledges, etc. free from ice, and where their situation was favourable, they undoubtedly were able to harbour a very poor and hardy vegetation. Particularly convincing, it seems to me, in this respect is the occurrence of 8 species on a small "nunataq" area near the north coast, in about lat. 81° N., which locality was passed by the Second Thule Expedition in 1916 and called by them the "Midgaardsorm" (i. e. the Midgard Snake). The conditions prevailing within this small area are, properly speaking, those of the glacial period, but in spite of this a few hardy species have been able to live there. They belong to the species which I call high-arctic (3) and arctic (5). From three other nunataqs plants were collected in 1878 by A. Kornerup and J. A. D. Jensen, the latter nunataqs being situated at some distance from the margin of the inland ice, in southern West Greenland (near lat. 63° N.) thus under much milder conditions, but at a height of between 1000 and 2000 m. On each nunataq there were 26 or 27 species, naturally in part the same; however, the total number of species was 54, of which 40 are arctic, 3 high-arctic and 11 subarctic and boreal[1].

These evidences and the circumstance that so very many species occur high up in the mountains, seem to me to make it probable that the hardiest part of the Greenland flora may have been living through the period of the maximum glaciation in the country itself. It is impossible to decide the number of species, any more than what species we are dealing with, but they must first and foremost be looked for among the high-arctic and the widely distributed arctic species[2]. Thus the problem can merely be dealt with in its general aspects, not numerically, and it only comes to play a small part in the understanding of the origin of the Greenland flora, the more so as it is more difficult to explain the immigration into Greenland of the less hardy species, which, besides, are the most numerous. In the subsequent attempt at unravelling the problem of the origin of the Greenland flora I have, consequently, been obliged partly to ignore the part played by this glacial (or pre-glacial) element.

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[1] For the definition of these terms see later p. 282.

[2] I suggest that the number of such glacial species in Greenland amounts to about 60.

III. THE DIVISION OF GREENLAND INTO PHYTO-GEOGRAPHICAL DISTRICTS AND THE PHYTO-GEOGRAPHICAL CATEGORIES OF THE PLANTS

In table I the country is divided into 15 phyto-geographical districts, and in each of them the 390 species are placed in various categories. The number of districts into which the country is divided is naturally a matter of opinion, but I do not think that our knowledge permits of a division into smaller areas than the one I have given[1].

In the definition of the districts (see table I) I have tried to consider the natural geographical and climatic conditions. The most northerly

Table I.

	W.		E.	
	83°—80°	*VIII*	83°—81°	
VII.	80°—76°	.	81°—76°	*VII.*
VI.	76°—71°	.	76°—72°	*VI.*
Va.	71°—69°	.	72°—69°, 30	*V.*
Vb.	Disko	.	Scoresby S.	*V.*
IV.	69°—66°	.	69°, 30′—67°	*IV.*
III.	66°—64°	.	67°—65°	*III.*
			Angmagssalik	*III.*
II.	64°—61°	.	65°—61°	*II.*
	61°—60°	*I*	60°—61°.	

The phyto-geographical districts of Greenland.

part (district VIII) I have kept separate and so also the most southerly part, which almost coincides with the old eastern settlement (I); this makes 7 districts on the west coast, Disko Island being set aside as a special area (district Vb) on account of the great number of more southerly forms which occur in the southern part of the island, and 6 districts on the east coast, of which the Angmagssalik district (E III) and the Scoresby Sound district (E V) each constitute naturally confined areas. The boundaries of the districts, which must naturally only be taken as approximate, are indicated by degrees of latitude.

Within each district I have counted the number of species and then distributed them:

1) according to their geographical occurrence outside Greenland (A—H) and

2) according to the phyto-geographical elements to which they are referred by their distribution (A_1—S); further I have indicated:

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[1] For some of the areas (districts E II and E IV) in the southern part of the east coast I have included a number of species that are not recorded from there, but occur both to the north and south of them, and so, in all probability, are to be found in the districts which, for that matter, have not been very thoroughly investigated, and form very poor habitats for plants, *inter alia* on account of the limited ice-free area.

3) how many of the species only occur in West Greenland and how many only in East Greenland, and

4) how many of them extend as far as the most southerly district (I).

The division of the species according to their geographical distribution

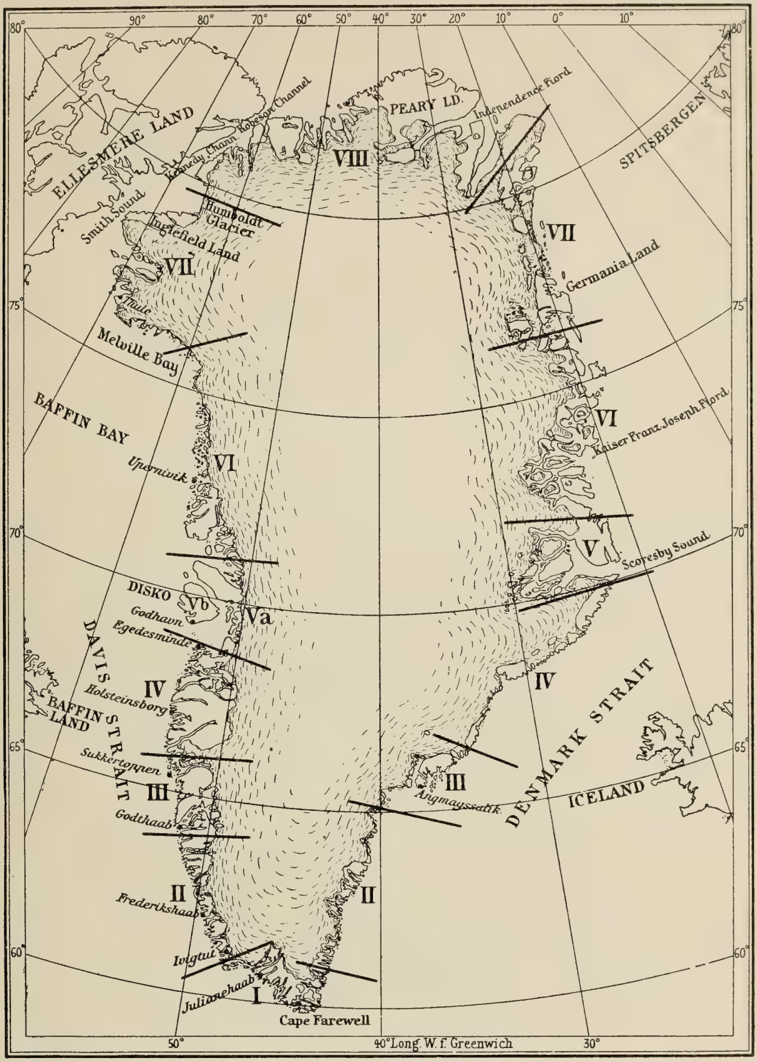

Fig. 1. Map of Greenland showing the phyto-geographical districts.

outside Greenland is based upon the floras of the surrounding countries. A species is always referred to the category which approximates it most nearly to Greenland. A species occurring in arctic North America and arctic Asia is therefore classified as American, and a species occurring in Europe, possibly in Iceland, and also in western North America is classified as European. The categories employed are:

A. Species which occur in North America, but not in Europe.
B. Species which occur in North America and in Iceland, but not elsewhere in Europe.
C. Species which occur in North America and in Europe, though not in Iceland and Scandinavia.
D. Species which occur in North America and in Europe, but not in Iceland.
E. Species which occur in Europe, but not in eastern North America.
F. Species which occur in Arctic Europe, but not in Scandinavia and Iceland, nor in North America.
G. Species which occur in North America, in Europe and Iceland (circumpolar species).
H. Species which are not known outside Greenland (endemic species)[1].

Further, according to their *general* geographical distribution, the species are divided into 3 phyto-geographical elements (types). In this division the author will naturally in some cases have to follow his personal opinion, as there are no sharply limited categories, and undefined cases are apt to occur. I have preferred to divide them into:

A_1. *High-arctic species, viz.* species which almost exclusively occur in arctic regions, and which are able to live under very severe conditions.

A_2. *Arctic species, viz.* species which are principally distributed over arctic regions, but also occur far outside (south of) the latter.

S. *Sub-arctic and boreal species, viz.* species which are principally distributed outside (south of) the arctic regions. Some of these are very well able to live in arctic regions (which probably has some bearing upon the fact that they, properly speaking, consist of several micro-species or perhaps often eco-species in Turesson's sense; others only occur in the most favourable parts of Greenland. From our point of view this category, which really consists of several categories, may be looked upon as a single class, and may also be termed "southern element" (which term is, for instance, used by Porsild).

The object of indicating how many of the species of each district extend as far as district I is to show the extensive distribution of some species and also the gradual increase southwards in the number of species, the latter circumstance, however, being rather a matter of course.

IV. THE NUMBER OF SPECIES ON THE WEST COAST AS COMPARED WITH THAT OF THE EAST COAST

Special interest attaches to the fact that a larger number of species occur only in West Greenland, while only a few are restricted to East Green-

[1]The few species (8) belonging to the latter category occur within the so-called critical genera (*Taraxacum, Hieracium,* etc.).

land. The great preponderance in West Greenland as regards particular species is, first and foremost, due to the great number of species which occur in the southernmost parts (district I), this also including the east coast from lat. 60° to 61° N., and of which a fairly large part (46 species), as will be shown later on, is due to the old Norse settlements. But apart from this there is, in the southern part of the west coast, far more ice-free country and so also better conditions for plant life, while the distance to the neighbouring countries is shorter and the possibilities of immigration consequently greater. Altogether 134 species have been found on the west coast which are not recorded from the east coast, or about a third of the total flora. On the east coast there are, on the other hand, only 9 species which are not to be found on the west coast.

V. CHARACTERIZATION OF THE INDIVIDUAL DISTRICTS

When examining the figures for the individual districts, the following may be inferred from table II.

The number of species naturally increases in the direction from north to south; some districts are particularly rich in species, *viz.* as far as the west coast is concerned (besides the above-mentioned southern district I) Disko (district W. Vb) and the district right south of it (W. IV) which is distinguished by its large ice-free area and deep fiords. As regards the east coast it has already been mentioned that districts E II and E IV are very poor in species, partly because they have so little ice-free land, and partly because they are not particularly well investigated. On the other hand, Scoresby Sound (E V) with its large system of fiords is comparatively rich; this is especially due to the fact that in its inner part, far removed from the cold and fogs of the Arctic Sea, a number of species occur which are otherwise not recorded from the east coast, or which generally do not extend so far north.

The three northern districts, *viz.* the north district itself (VIII) and the adjoining districts on the west and east coast (W VII and E VII) are the poorest parts; they constitute a naturally confined whole, which I call North Greenland (north of lat. 76° N.). This area comprises 125 species, and of these 8 high-arctic species are characteristic of this part and not found elsewhere in Greenland.

Table II further shows the interchanges in the numbers of the three phyto-geographical elements within the individual districts. If for distinctness this is translated into percentages (see table III) we get a number of figures which clearly illustrate the fact that the number of high-arctic (A_1) species constituting 57 per cent. of the total number of species in district VIII gradually drops to 1 per cent. in district I (district E II has 0 per cent.,

Table II.

District	N	West Greenland							S	East Grenland						N	Whole Greenl.
	VIII	VII	VI	Va	Vb	IV	III	II	I	II	III	IV	V	VI	VII	VIII	
A.	10	18	17	25	26	30	28	24	24	9	8	6	11	10	8	10	53
B.	1	1	1	1	2	1	2	2	2	2	2	1	1	1	1	1	2
C.	14	14	15	18	15	10	4	2	2		2	4	14	18	13	14	26
D.	18	20	30	34	38	36	29	23	22	10	17	18	33	27	18	18	56
E.		1	1	4	4	9	7	15	24	8	10	3	6	2	2		32
F.	2	1	1	1	1								3	2	1	2	4
G.	30	57	90	121	140	155	159	161	184	137	140	97	101	71	53	30	209
H.	2	2		2	3	4	4	5	5	2	2				1	2	8
Sum.	77	114	155	206	229	245	233	232	263	168	181	129	169	131	97	77	390
A_1.	44	52	41	43	37	28	9	2	2		9	16	39	45	41	44	58
A_2.	30	51	94	113	116	114	106	90	85	80	89	85	104	70	49	30	130
S.	3	11	20	50	76	103	118	140	176	88	83	28	26	16	7	3	202
W. Grl.		9	8	24	32	48	45	52	87								134
E. Grl.											3	1	6	5	2		9
Reaching I.	32	52	93	122	155	172	192	209	263	166	161	102	103	70	49	32	

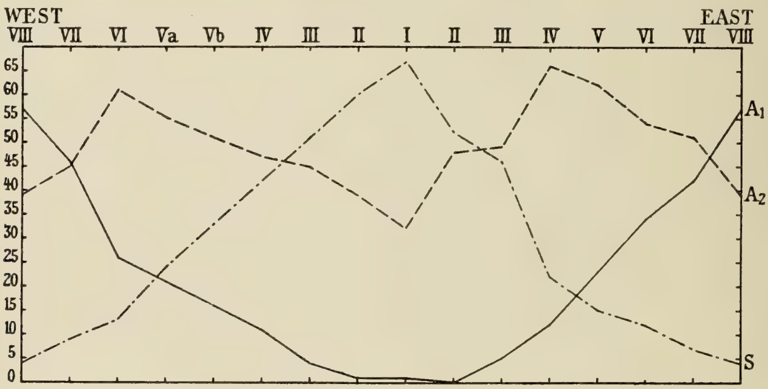

Fig. 2. Curves showing the percentages of the 3 phyto-geographical elements in the various districts.

Table III.

	East										West					
	VII	VI	Va	Vb	IV	III	II	I	II	III	IV	V	VI	VII	VIII	
A_1....	*57*	46	26	21	16	11	4	1	1		5	12	23	34	42	*57*
A_2....	39	45	*61*	*55*	51	47	45	39	32	48	49	*66*	*62*	54	51	39
S.....	4	9	13	24	33	42	51	*60*	*67*	52	46	22	15	12	7	4

The percentages of the 3 phyto-geographical elements within the various districts of Greenland.

A_1. High-arctic. A_2. Arctic in a wider sense. S. Sub-arctic—boreal.

but this has undoubtedly some bearing upon the above-mentioned poverty of the district), and that the number of the sub-arctic and boreal species (the southern element) increases from 4 per cent. in district VIII to 67 per cent. in district I. This is what might be expected. It is, however, interesting to note the circumstances relating to the common and widely distributed arctic species; they are most numerous in districts W VI and Va and E IV and V, where, therefore, the conditions must be supposed to be particularly favourable for their occurrence; the number of species drops from these two maxima, both towards the north, where its minimum is in district VIII, and towards the south with its minimum in district I. This distribution of their percentage in the flora points in the direction that the rough estimation of them as arctic species in a wider sense in contrast to the high-arctic on one hand and the sub-arctic and boreal species on the other has been essentially correct.

VII. THE IMMIGRATION OF THE SPECIES

From table II we may draw several conclusions as to the *distribution* of the Greenland species outside Greenland. The bulk (G) have a circumpolar distribution, and consequently they do not in their distribution show anything as to whence they have immigrated into Greenland. The few endemic species (H) have already been mentioned (v. footnote p. 282). It is probable that the 4 *Hieracium* species are derived from European parents, while the other 4 species have American relations. Now the species remain whose distribution should give us a hint as to whence they came.

The species pertaining to the categories A (53) and B (2) may be reckoned as coming from America, and those to E (32) and F (4) as coming from Europe. We are confronted with greater difficulties in the case of group C (26 species) which partly comprises a few sub-arctic and boreal types (4), in all probability immigrated from America; partly some high-arctic (17) and some arctic (5), which may just as well have come to Greenland from Spitzbergen as from arctic America; in the case of some of the latter their occurrence within Greenland may show whence they have probably come: *viz.* 4 from the west and 1 from the east; as to the remainder (17) nothing can be said for certain; they may have survived the glacial maximum in Greenland. Similar conditions apply to group D (56 species). Here 20 must be reckoned as having in all probability come from America and 6 from Europe, some (4) of which, however, belong to the subsequently mentioned plants from the old Norse colonization. There then remain 30 species of uncertain origin (partly glacial).

According to these considerations 87 species can with probability be said to have immigrated from North America. Of the remaining 209 circumpolar species 26, according to their distribution in Greenland, can certainly

be thrown into the balance in favour of America, which makes 113 American species. To this must be added, however, as a very important circumstance, that when a species according to its distribution in Greenland, as well as outside Greenland, may just as well have come from America as from Europe, the greater proximity of America makes its immigration from America probable. Consequently, there is no doubt that the figure 113 (29 per cont.) is a minimum figure, which certainly ought to be much greater. The European contingent, on the other hand, consists of 74 (19 per cont.) species, of which 50 are old Norse plants (15 of which are included in the figures 32 of Group E and 4 in Group D).

The remainder of the flora, *viz.* 203 species (52 per cent.) do not give any direct indication as to their origin, but as said above it is more probable that they have come from North America, apart from the unknown number of surviving glacial species (guessed to be about 60 species).

The distribution of the species within the individual districts offer several points of interest, as will appear from the tables. The pronouncedly American species are comparatively well represented in the most northerly part of West Greenland, as several of them are high-arctic. On the other hand, a number of the American species occurring in the more southerly part of West Greenland are sub-arctic and boreal; several of these really belong to the forest regions of northern America.

Of species which have immigrated to East Greenland, may be mentioned some European high-arctic types in the most northerly part and a few sub-arctic and boreal ones at Angmagssalik. —

On the other hand, it is worth mentioning that there are, naturally, species in Greenland which are widely distributed over the whole of the country—we have already referred to the 32 which are to be found all the way from north to south—and other species whose distribution is more limited. The rarest species are those which have been found only in a single place; further, a not inconsiderable number only occur in one district, although in several places there. Particularly rich in such rare species is the southern district (I), which has 36 separate species. From there it is a great distance to district W II with 6 species, W IV with 4, W III with 3, W VII, E III and E V each with 2 and W VIII and E V with 1 species each. Species of such limited distribution must rather be supposed to have newly immigrated, whereas such which are widely spread must be supposed to have lived in Greenland for a longer time. Among the pronouncedly American species there are some which furnish excellent illustrations of all these circumstances. —

As to the ways by which the species may be supposed to have immigrated into Greenland a few words may be said. The distance between North America and Greenland is shortest towards the north across Smith Sound and Kennedy Channel, and it is a natural supposition that this approach

has been greatly used and is still used by the plants; thus two species of *Pedicularis* are in Greenland only to be found in Inglefield Land, having probably in recent years immigrated from Ellesmere Land; they occur in the whole of arctic North America. As a matter of course particularly the high-arctic and arctic species have followed this route of immigration, and some of them have merely gone to the south in West Greenland, whereas others have gone also northwards and then down the east coast.

In 1905 Ad. S. Jensen drew attention to some layers of shells in the Vaigat District (about 70° lat. N.), where remains of bivalves occurred, which at the present time are not to be found in Greenland, their northern boundary at the present day being at St. Lawrence Bay. As these layers of shells are considered post-glacial, these bivalves are indubitable evidences of a warmer post-glacial period, during which a number of species of American plants, which at the present time are not supposed to be able to immigrate by a route as northerly as across Smith Sound, may have used this approach. At a later period they have then been driven farther south.

However, also in more southerly localities West Greenland has received a fair contingent of American species, *viz.* the sub-arctic and boreal types, which must have come across Davis Strait, probably chiefly from Baffin Land and Labrador.

If we then turn to East Greenland, there are, farthest north, some species which must have come across from Spitzbergen and other arctic European islands, and farther south, in the Angmagssalik District, we meet a small number of species which must be supposed to have immigrated from Iceland.

The manner in which all the species have been able to immigrate is a problem which in many cases is by no means easy to solve. The natural methods of immigration are by the agencies of water, wind and animals. As far as Greenland is concerned, water in its usual fluid state has no great importance as a medium of immigration, seeing that only very few species of shore plants occur. On the other hand, special emphasis must be laid upon its great importance when in a frozen state. Where the sea-ice lies solid during the winter, it forms an excellent highway, along which seeds and pieces of plants may be carried by the wind, which at that very season often blows with particular strength. A distance like the one across Smith Sound is nothing when there is a cover of ice.

If, on the other hand, the ice is carried along by currents, as frequently happens off the coast of East Greenland, it is certainly also possible that vegetable matter may be carried along from other countries, and this explains the occurrence of easterly arctic species in northern East Greenland; several of the characteristic species are even limited to the outermost coast belt, which seems in favour of this supposed manner of immigration.

The part played by the wind in the dispersal of the seeds within these

regions is undoubtedly very great, particularly in winter, when the surface is covered by snow or, as just mentioned, by ice. Most Greenland species have small seeds.

Finally, as regards carriage by animals, or, rather, by birds, several of the species have fleshy fruits which spread through the agency of the birds, and these latter in other ways, when wandering between Greenland and the coasts of North America, may further immigration. Consequently, I do not think that as far as Greenland is concerned it is necessary to have recourse to land bridges in order to explain the immigration of the plants.

VIII. THE BOTANICAL IMPORTANCE OF THE NORSE COLONIZATION

In conclusion mention should be made of the part which the Norse colonization of Greenland (extending over a period of 400 to 500 years from 985 or 986 A. D.) must be supposed to have played in the composition of the flora of southern Greenland. As to this no direct information is at hand. The various sagas are curiously reticent as regards what was carried by the vessels by way of food for men and animals, but we know that the sea-farers had live cattle and sheep on board. The provisions in all probability consisted of grain (flour), salt meat and then the live cattle and sheep which could supply milk and butter. But these animals, in their turn, must be fed with hay, from which it may be concluded that the vessels would carry very considerable quantities of this commodity. When they arrived at their destination, the ships must undoubtedly have been cleaned and brought ashore for the winter, and the offal from the hay-fodder might then easily be thrown away, and so there was a possibility that some of the seeds which had been brought along, might come to rest at places where they were able to germinate. Further, this hay-offal must be imagined as having been very variegated. The sowing of pastures with one or only a few kinds of plant seeds was unknown in those days, and as a matter of fact this is still the case in Iceland and some parts of Norway, which two countries must be considered as the purveyors of the Greenland hay and plant-seeds, as they nearly alone kept up communication with the Norse settlements.

The cattle and sheep which the sea-farers carried with them were, however, not only to serve as food during the journey; they were also taken ashore in Greenland, a natural consequence of the fact, mentioned in detail by the Icelandic professor Finnur Jónsson (1893), that dairy-farming played a great part in the economic life of the old Norsemen, and the information given in the "King's Mirror" to the effect that "much butter and cheese is made." Also the ruins found of the old habitations show that the farms, like those of Iceland, were surrounded by fenced-in yards (tún).

Everything considered, there is thus much indirect evidence that there has been ample opportunity of carrying seeds from Europe (particularly Iceland and Norway) to Greenland, and in the present flora there are several species (for instance *Vicia cracca*) which have strictly kept to the immediate surroundings of the old farms, particularly the old bishop's see Gardar at Igaliko. That these species owe their occurrence in Greenland to the old Norsemen, of that there can be no doubt. It is more difficult to say anything for certain as regards species which have thrived better and which in the course of centuries have had the opportunity of spreading and coalescing with the original vegetation. In the case of the latter all that can be arrived at are more or less well-founded suppositions.

Plants which may possibly come under the category "old Norse plants" should have a distribution corresponding with the areas of the old settlements, which are now well known, thanks particularly to the comprehensive researches of Daniel Bruun. Further, they should be species living in Iceland or Norway, and finally their habitats should be such that it is possible to think of them as having been imported with hay from meadows and grasslands. There are in all about 50 species of flowering plants[1] which may be said more or less to comply with these conditions, which from the point of view of distribution means that they principally only occur within an area from the most northerly part of Godthaab Fiord in the north, southwards to Lindenow Fiord in the very most southerly part of the east coast, *viz.* corresponding with the phyto-geographical districts W III—I. Most of these are meadow or grass-land plants, and no less than twenty are grasses or grass-like plants. The greater number of these species only occur in district I, which corresponds with the "Eystri bygd," the largest old Norse settlement. Several of those which extend farther north are lacking in district II and only recur in district III, Godthaab Fiord, the old "Vestribygd." Consequently it may be estimated with a certain degree of probability that almost an eighth of the Greenland flora (nearly 13 per cent.) has been brought to Greenland by the old Norse settlers.

As mentioned above (page 285) these species must be added to the number of species which have immigrated from Europe, in which manner *a total of about 74 European species* (19 per cent.) is *obtained*. Thus there are *316 species* (i. e. more than four-fifths of the whole of the flora) which *must be supposed to be of American origin or, for the smaller part, to have survived the maximum of the glacial period in Greenland.*

[1] I do not include the pteridophytes, as their small and light spores make them more fit to be spread by the agency of the wind across great distances.

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THE VEGETATION OF GREENLAND

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The vegetation of Greenland may naturally be viewed under the following three heads, which are to be dealt with separately, *viz.*

1) The oceanic vegetation.
2) The vegetation of the inland ice and the snow.
3) The vegetation of the coast lands, which are free from ice and which only make 5 to 6 per cent. of the total area.

I. THE OCEANIC VEGETATION

The oceanic vegetation consists of two large communities: the plankton and the vegetation fixed to the bottom.

Plankton denotes, as is well known, the very small, for the greater part microscopically small, animals and plants that float or swim freely, particularly in the upper layers, and are carried along unresistingly by the currents, frequently occurring in such large quantities as to lend a peculiar colour or tinge to the waters. On his journeys between Denmark and Greenland K. J. V. Steenstrup investigated the colour of the water and laid down in charts the various colours which are to be found in different longitudes and are in part due to communities of minute organisms. More accurate investigations of the organisms occurring in the various places and at various times, as dependent upon the temperature and salinity of the water, have been undertaken by Vanhöffen in the Greenland Sea and by C. H. Ostenfeld and O. Paulsen in other places.

Wherever *Diatomaceae* prevail, the water is muddy, of a greenish or brownish tint. Vanhöffen found numerous *Diatomaceae* of the genera *Chaetoceras*, *Thalassiosira*, *Coscinodiscus*, and many others; further, a number of *Peridineae* and other *Flagellata*, motile organisms which must rather be considered as forming part of the vegetation. In Davis Strait there are at times enormous, almost pure communities of *Thalassiosira Nordenskiöldii (Diatomaceae)*, particularly in the month of August, whereas the

Chaetoceras reaches its maximum in the month of September, but otherwise the composition of the communities changes according to locality or season. Closely related with these investigations are those of Ostenfeld and Paulsen in 1904.

The fixed bottom-vegetation almost exclusively consists of marine algæ, which are attached to rocks or other solid objects. Of the sea-grass communities living in loose soil there are only the faintest suggestions, particles of *Zostera marina* having drifted ashore in Godthaab Fiord to where it has perhaps centuries ago been carried by the old Norsemen.

At an early period the marine algæ attracted the attention of investigators. Thus Rink, in 1852, mentions the most striking representations of this growth-form, the forests of huge brown algæ (*Laminaria* species) which at times attain a length of 3 to 5 metres and the corrallaceous crustations of calcarous algæ coating the rocks. But the first scientist who deals exhaustively with the subject is Kolderup-Rosenvinge in his "Algevegetationen ved Grønlands Kyster;" besides, he has given systematic summaries of the species (1893, 1899).

These numerous algæ are distributed in many different associations according to the oecological factors: temperature and salinity of water, tides, ice conditions, light and wave violence. In this connection it is only to be noted that the temperature of the surface water is almost as that off the coasts of Spitzbergen and Novaja Semlja, *viz.* in winter below zero, in the summer months 1 to 3°; an exception is, however, the Disko Bay which has a temperature of 4 to 7° in June—July. In the interiors of the fiords higher temperatures may occur. The salinity is, however, somewhat lower in the Straits than in the Atlantic, *viz.* 3.3 to 3.4 per cent.

Tides there are everywhere, on an average about 3.14 metres for springtime, 1.6 metres for slack-water. A very important part is played by the ice, though different in the different places; farthest north it is more or less stationary all the year round, whereas in South Greenland the open sea never freezes over. Of some significance to the vegetation is the "ice-foot," i. e. the rim of the ice attached to the rocky coast from above the high-water mark and over a shorter or longer distance down towards the low-water mark. It forms in the autumn, disappears in the summer at somewhat varying periods and undoubtedly plays a part as far as the differences of the shore vegetation are concerned.

The coast otherwise favours a rich and varied algal vegetation, as it is greatly indented, a typical "Skærgaard" or skerry fence with places exposed to the violent beating of the waves, and others which are sheltered; consequently, different communities flourish in the different habitats. Furthermore, the character of the rocks is very different: some are greatly cracked and grooved, others much smoother, and this also makes for diversity. There is a difference in the intensity of light and the depths to which it penetrates,

partly according to the latitude, partly according to the quantity of plankton or deposited particles of clay, or the extent to which the sheet of ice covering the surface reduces the light.

In view of all of these different oecological factors the number of associations must naturally be very great.

Rosenvinge divides the algal vegetation into two regions:

1) The littoral, between the upper limit of the algal vegetation and the lowest ebb-mark, and
2) The sublittoral.

The *littoral region.* In South Greenland there is a fairly luxuriant littoral vegetation, at any rate as far as Upernivik. Farther north it evidently becomes much sparser, and where the sea is covered with ice all the year round, it must be entirely wanting, the ice-foot necessarily greatly checking the development of the plants. At Prøven and Upernivik Rosenvinge mostly found brown algæ (*Fucus inflatus* and *Ascophyllum nodosum*) which in sheltered places may form a dense vegetation. Somewhat farther south *Fucus vesiculosus* and *Ascophyllum* also form communities in regular succession. An important factor is also the power of the various species to endure drought when laid bare at ebb-tide.

In botanical literature a special part has been assigned to the "algal margin," *viz.* the zone of algæ, in particular *Fucus vesiculosus* and other *Fucaceae* which, together with the white shells of *Balani* form the upper limit. Steenstrup maintains (1907) that this margin can be utilized for determining changes in the water level when photographed with intervals of many years from exactly the same place. The ice-foot upon the whole lies higher than the algal zone.

Particular associations are found in the water holes in the rocks. At the upper margin of this zone and above it there are also crustaceous lichens, as *Verrucaria maura* along the Danish coasts.

The littoral region is otherwise more especially characterized by the above-mentioned three species of *Fucaceae*, which in sheltered places may be so numerous that hardly any other algæ are visible at first sight. Where the movement of the waves is strong, other associations prevail, e. g. the *Monostroma Groenlandicum* association.

The *sublittoral region* may occur everywhere along the coasts of Greenland, from the very northernmost; its vegetation is richer, stronger and composed of other species; in this locality it is more particularly the huge *Laminariae* which form associations. Some may attain a length of about 15 metres and a width, in the leaf-like part, of up to 1 metre. Together with these are found other huge brown algæ of the genera *Alaria*, *Agarum*, *Saccorrhiza*, and in these "forests" there are *Epiphytes* and a sub-vegetation consisting of small red and brown algæ. Also associations of these species and of red algæ, e. g. *Lithothamnion* occur, and the rocks may be covered with

crustaceous species. At the border of the littoral zone there is always a very rich plant growth. The red algæ become more numerous with increased depth.

It is difficult to determine the lower limit of this region, but in the arctic seas it is most frequently put at 20 fathoms (37.6 metres). Rosenvinge does not recognize any elittoral region, but in the sublittoral region there may be a loose substratum where detached algæ can form and lie multiplying, at any rate for some time.

II. VEGETATION ON ICE AND SNOW

This vegetation is naturally extremely poor, though represented by a few algæ. As far as is known, the famous English polar explorer Ross was the first to draw attention to the occurrence of "red snow" in the otherwise shining white desert. At a far earlier period it had been observed in Central and South Europe and examined, for instance, by Saussure. Ross pictured snow fields in North Greenland, which he called by the name of "crimson cliffs."

It is the minute, almost microscopical, spherical *Chlamydomonas nivalis*, *Ch. lateritia* and other low-organized green and yellowish-brown algæ which, over larger or smaller areas, in infinite quantities fill the upper layers of the snow to a depth of a few decimetres. It is a curious instance of a plant cell, devoid of any kind of protection against the extremely low temperature of the arctic countries. In that vegetation period it is surrounded by water with a temperature of about 0°. The red colour is probably of great importance to the life of this plant, in the same manner as red colours are supposed to be of significance to numerous other arctic plants, mosses as well as phanerogams, this importance presumably consisting in the quality of absorbing heat. As with us the red colours are more especially spring shades in the arctic countries. According to information given by M. Porsild they are most pronounced at the very beginning of the vegetation period, being then of *universal* occurrence. In the autumn the red colour again appears in perennial leaves, but at the same time red and yellow tints occur in leaves which are on the point of withering. The most vivid red and yellow tints occur in the following deciduous leaf-shedding plants: *Arctostaphylos alpina*, *Myrtillus uliginosa*, *Salices*, *Betulæ*. The most pronounced red tints in fresh leaves occur in *Diapensia*, *Saxifraga tricupidata*, *Chamaenerium latifolium*, *Empetrum*, *Polygonaceae* and *Campanulaceae;* they are far less pronounced in *Cassiope tetragona* and *Dryas*.

On his journey across the ice in 1870 Nordenskiöld's attention was attracted by a greyish-brownish dust, which lay scattered over the inland ice; as we now know, this is mineral dust which originates in the weathering of the mountains and which, when gathering here and there in large quan-

tities, melts cavities in the ice, 1 to 30 centimetres in depth, while at the same time absorbing the heat of the sun. He called it "cryoconite," and his companion, the botanist Berggreen, found the cryoconite admixed with *Diatomaceae* and a hitherto unknown not subsequently identified alga: *Ancylonema Nordenskiöldii.*

III. THE VEGETATION OF THE COAST LAND

The flora of Greenland is described in a previous article. As to the grouping of the species in communities of a definite, characteristic composition the following facts may be given for South-west Greenland, while for the rest the reader is referred to the following literature: Warming 1887, N. Hartz 1894, L. Kolderup Rosenvinge 1898, C. Kruuse 1898, 1911, M. P. Porsild 1902, 1911, Lundager 1917, Ostenfeld 1927, as well as scattered remarks in Berggreen and others.

A. *Oecological Factors.*

The vegetation of a country depends upon two groups of factors: climatic and edaphic (originating in the soil), the latter including topographic. As far as the *climatic* factor is concerned, one must *a priori* expect rather great differences between the most southerly and the most northerly areas of a country covering nearly twenty-four degrees of latitude. Thus it appears that the vegetation of the south coast, the area which Rosenvinge calls the Julianehaab District, is the most luxuriant and abounding in species throughout Greenland, and the farther north the poorer and more stinted the vegetation, an exception being formed by the Godhavn region. It is naturally the lower temperature which causes this decrease. The cold checks or stops the energy of growth of the plants, makes them undersized and stunted, with short shoots and closely set branches, the plant thus assuming the so-called tufted or cushion shape, while also the rosette formation becomes more common. For the same reason a greater altitude above sea-level naturally produces similar variations, but otherwise the same communities of plants, the fell-field, which are, to be found in the highest altitudes, may also occur at the level of the sea, the reason being the great contrasts of temperature which make themselves felt between the coast margin with its lower summer temperature and frequent fogs, and the lower lying sunny tracts of the interior, with the higher summer temperature. This explains why, according to Rink, "berries" always ripen in far greater quantities in the interiors of the fiords than in the immediate vicinity of the sea.

Of the utmost importance to the vegetation is the average humidity of the climate, and here again there are great differences between south and north, between skerry fence and inland. The farther north the drier the climate. Add to which the greater amount of precipitation is in the form of snow, and

the vegetation consequently only profits by it indirectly, as melting water, when the earth has attained a certain degree of heat.

In a similar manner atmospheric humidity and precipitation evidently decrease from the skerry-fence inwards, in the direction of the inland ice; it is known from of old that the climate in the long fiords of the west coast in the summer months is much drier and warmer than farther out. Inside the mountains of the broad coast land between Egedesminde and Godthaab Nordenskiöld, in 1874, found a large hilly lowland with deposition of salt, lakes without outflow, frequently with saline water, a stepp climate, which one would not expect to find in the Polar countries, natural conditions which together with their fauna and vegetation should be made the subject of closer investigation. In a still higher degree drought seems to prevail along the coasts of East Greenland, as soon as one gets away from the sea and penetrates into the deep fiords or climbs the high mountains. An essential cause of the dryness of the atmosphere on the east as well as on the west coast are the violent, dry and warm föhn winds; they leave their stamp on the vegetation, in particular when the air is so cold that the roots of the plants cannot replace the water evaporated.

Cold and drought are two factors which together leave the strongest impress on the vegetation of the strictly arctic parts of the country. They are the cause of various peculiarities in the shapes of plants—the above mentioned cushion-like and tufted appearance of many herbs and dwarf shrubs, the prostrate growth of many bushes and dwarf shrubs, which press their shoots against the soil like espalier plants made fast to a wall, these shoots frequently attaining a height of up to a metre, whereas the height of the erect shoots is merely measured in centimetres. The reason is that the plants seek the greater amount of heat and shelter to be found close to the ground, and that the winds desicate the shoots which stand out above the rest. From the east coast Kruuse mentions and describes such espalier bushes and taller shrubs, the branches of which are deadened by desication as far down as they are uncovered by snow in winter.

That the radiation of the heat from the soil also plays a part in the life and development of the taller shrubs appears from the observations made by Hartz, *viz.* that the more outstanding willow branches foliage and flower at a later period than the lower ones, because they live in a higher temperature that the former, whose temperature only differs very little from that of the atmosphere.

Also the root system of the plants is influenced by the climate, in so far as the soil, which at that low depth is too cold or, perhaps, even frozen, gives rise to often enormously long roots, extending horizontally in the upper layers.

While older oecologists, as for instance Griesebach, was of opinion that the low temperature was the factor which more that any other contributed

towards shaping the vegetation of the Polar countries, this view has been abandoned, as it is now put after the degree of humidity of the atmosphere and the soil.

In other respects than those mentioned above the strong evaporation leaves its impress on woody plants as well as on herbs, as described in detail by me in 1887, particularly in section V. Here mention is only to be made of the devices by which foliage adapts itself to drought *(Xeromorphy)*, *viz.* by their shapes and their anatomical structure, by coatings of hair, the lie of the shoots, etc.

After these remarks on the impress left on the plants by cold and strong evaporation, I shall briefly mention the factors which play a part in the development of the various plant communities.

In a mountainous country like Greenland, these communities are to a very large extent subdivided, all of these subdivisions being scattered in the nature of mosaics over the landscape. The heights of the surface are extremely varying, and this also holds good of the oecological factors; large horizontal levels in which a uniform vegetation is able to develop, such as occur in great abundancy in Denmark, are rare. They are mostly to be found on alluvial soil, round the rivers, in the bottoms of valleys and particularly at river deltas.

The factors which especially contribute to the diversity in the nature of the habitats of plants are mostly connected with the *humidity and temperature of the substratum.* The exposure in relation to the points of the compass is of the utmost importance; one side of a mountain range or peak may bear a vegetation which is very different from that of the other sides; one slope may remain covered with snow, long after the other is bare of snow and dried by the heat of the sun. The *declivity of slope* is also significant; the nearer to a right angle the incidence of the sun's rays on the substratum, the greater the heating power, and the sooner the snow disappears from the ground; the greater the declivity of slope, the quicker the melting water runs off the latter and the quicker the drying of the substratum. The intensity of the radiation of the sun appears from the many experiments with blackened thermometer bulbs, undertaken by English, Danish and Swedish travellers[1]; for instance, near Christianshaab on July 28th, I registered 40° with a blackened and 36½° with a blank bulb in the shelter of a stone at the level of the vegetation.

The thickness and duration of the *cover of snow* is a factor of extreme importance. Whether the snow remains or is swept away by the storms, so that it gathers in drifts, depends upon how exposed the ground is to

[1] See Warming 1887 — Rosenvinge: Botanisk Tidsskrift 16.

winds, and how strongly the heat of the sun acts upon it. At the edge of the melting snow-drifts vegetation develops gradually, and a succession of belts with small differences of vegetation form around them. Frequently occurring in descriptions of the Alps, Scotland and the Scandinavian peninsula are the moist "snow valleys" on which a kind of mould gathers, which originates in the dust absorbed by the snow, and where a characteristic, sparse flora appears, chiefly represented by *Salix herbacea*, *Cassiope hypnoides*, *Anthelia julacea*, *Cesia coralloïdes*, and others. Corresponding communities are to be found in Greenland.

Level ground generally yields a wet, swampy and cold soil with stagnant water, poor in oxygene, the substratum of swamps and moors. As instanced by Hartz the height above the ground-water is a very important factor. Flowing water becomes rich in oxygene and gives an entirely different vegetation.

The *nature of the rock* is also of vital importance to the physical nature of the substratum, and so also to the moisture and heat contained in it. It makes a radical difference whether it disintegrates more or less easily; basalts and slates with their tendency to crack form a substratum, from which the water flows easily away, and it is an essential point whether the substratum becomes so loose that the angle of inclination makes it apt to shift and slip down. It is also important whether the alluvial formations are sand or clay or mixtures, because the water capacity is different. On the other hand, the chemical differences of the soil hardly play any part other than an insignificant floristic one.

In some formations conditions are so that the detached particles of plants remain and cover the soil with humus, as a rule evidently sour humus, so that raw humus occurs far more frequently that neutral humus.

B. *Plant-formations.*

The above-mentioned climatical and edaphical factors are naturally combined in a widely different manner, and the number of small habitats thus becomes very great (cf. G. Kraus's investigations on "Boden und Klima auf kleinstem Raum," 1911). By far the greater number of communities are extremely composite. If, however, an attempt is made to embody them in larger unities, one should, as the chief principles of classification, consider whether the vegetation is open or close; whether the substratum is merely mineral or contains humus; whether it is solid rock or loose masses; what is its degree of humidity; whether it is exposed to winds or sheltered, and whether the reigning growth-forms are woody plants, herbs or grasses, mosses or lichens.

The classification adopted in this treatise is the following:

1. Fell-field and steep rocks as well as large stones.
2. Dwarf-shrub-heath, lichen-heath, moss-heath.
3. Copses.
4. Herb-field and grass-field in well-ventilated soil.
5. Fresh waters.
6. Moors and meadows.
7. Strand-vegetation.

1. *Fell-field.*

Fell-field was the term which I used in 1887 of the formation, the conditions of which are so poor that the substratum is never completely covered by vegetation. The plants grow singly, often with great intervals, though here and there denser spots of vegetation occur, consisting of one or more species, and it is the substratum (loose soil, rock) which lends its generally grey or greyish black tinge to the surface. The substratum, however, varies greatly; solid rock, smaller or larger stones, which have fallen from the face of the rocks, gravel, sand or clay, all yielding different variations of fell-field, but common to them all is the open and low vegetation, stunted by cold and storm; humus does not form, partly because the vegetation is so sparse and low, and partly because the detached particles of plants are generally swept away by the wind. The plants are more or less battered by the storms, "wind-worn" by the sand, gravel or pebbles which the wind carries along with it.

The flora in the main consists of the very hardiest of the Greenland cryptogams, lichens, and mosses, as it were the arctic flora in its purest form. Of woody plants there are a number of dwarf shrubs, chiefly represented by *Ericaceae; Empetrum nigrum, Cassiope tetragona, Myrtillus nigra, Loiseleuria, Rhododendron lapponicum, Salix glauca* and *S. arctica, Diapensia lapponica, Dryas integrifolia,* and in the northernmost parts *Dryas octopetala.*

Nearly all of these species are represented by low espalier shrubs or low, close tufts; their branches are bent and gnarled, because cold and drought check their energy of growth; frequently the espalier branches are seen to turn away from the wind side, or the plants to become crescent-shaped, because the winds destroy one side, as appears most distinctly from photographs taken by Jessen and especially by Kruuse. Their roots only extend to shallow depths, because the soil is frozen or too cold; they run horizontally in the warmer upper layer, attaining a length of about a metre. The greater number of species are evergreen (15 out of nearly 20), and the leaves are therefore pronouncedly xeromorphous.

Of herbaceous plants a number of species occur. First and foremost must be mentioned the arctic yellow poppy (*Papaver radicatum*), the fresh-green tufts and pink flowers of *Silene acaulis, Saxifraga oppositifolia* and other species of *Saxifraga*, species of *Draba, Campanula, Cerastium, Erigeron,*

Melandrium, Oxyria, Pedicularis, Polygonum, Potentilla, Ranunculus, Rhodiola and *Sibbaldia*, among dicotyledoneous plants. Furthermore, *Juneaceae* (the genera *Juncus* and *Luzula*), grasses (the genera *Agrostis, Aira, Calamagrostis, Festuca, Poa, Trisetum*), *Cyparaceae* (a number of *Carex* species, *Cobresia;* among vascular Cryptogamia a number of ferns (*Woodsia, Cystopteris, Lastraea*), species of *Lycopodium* and *Equisetum.*

The herbs are also stamped by the climate, rosette-shaped shoots and tufted plants being extremely common; the shoots are so closely set, and the formation frequently that of cushion plants, which are particularly characteristic of many high mountains in the Alps, in South America, New Zealand, etc. where natural conditions are the same as in the fell-fields of arctic countries. In these cushions temperatures have been registered which were above that of the surrounding atmosphere; they are extremely well fitted to remain warm, while moisture readily gathers between the closely set shoots. Also the rosette formation has its advantages, as the shoots are perennial, and in many species the leaves keep green throughout the winter, the latter apparently being ready to resume the work of assimilation as soon as conditions become favourable on the arrival of spring.

Mosses and *lichens* play a very great part among the growth-forms of the fell-field, and more particularly they may form small communities, small sections of moss-tundra and lichen-tundra. Also the mosses are frequently tufted or cushion-like in shape. Of the lichens the crustaceous species seem to preponderate, besides the grey or pitch-black *Gyrophorae*, whereas shrub-like species, as for instance reindeer lichens, are not sufficiently hardy to develop in larger associations.

Of the variations of fell-field particular mention should be made of the *steep rocks* which are unfitted to bear rooted vascular plants, except in small clefts in the stone or on ledges in the walls where small quantities of mould and moisture are able to gather. Lichens and mosses make the prevailing growth-form, and the lichens are mostly crustaceous. Of these there are some which, by their lively colours, lend a striking tinge to the rocks. Thus travellers frequently mention *Xanthoria elegans*, which conveys a tawny tinge, but the colours of most lichens are grey or dun, and even the mosses themselves are greenish-brown or dark-brown, as for instance *Andreaea.* The same *Thallophyte* formations occur on loose stones and moraine blocks.

On the steep walls of rocks broad, vertical *black-stripes* are frequently to be seen: they consist of *Cyanophyceae* and rudimentary lichens (*Stigonema, Scytonema, Ephebe*) and indicate places along which the water oozes down from the higher parts. Like the snow-algæ these plants are at times curiously hardy, water-soaked, when the mèlting water runs down upon them, in periods of drought exposed to very high temperatures and sudden changes of temperature, especially in places where the rays of the sun fall directly

upon them (Porsild registered 48° in a sheltered position and with a blackened thermometer bulb), and in winter they are in many places subjected to the highest negative temperatures, because they rarely have a protecting cover of snow. The ice over them has, by Hartz, been observed to melt earlier than on the rock beside them.

The vegetation of the fell-field otherwise varies according to conditions: direction of winds, humidity, nature of soil, etc. There are places where it is extremely poor and desiccated, as on the huge talus at the foot of the basalt mountains, or on wind-swept plateaux and in valleys, on wet and moist sand and gravel surfaces, etc., but in a few places it may be abundant and pass into dwarf shrub-heath and herb-fields.

Curiously enough, none of the travellers visiting West Greenland seem to mention the "Polygon field", which occurs in descriptions of so many places along the north coast of Siberia and in the countries to the north of the latter, as Spitzbergen, Iceland and East Greenland. From North Greenland Th. Wulff mentions Polygon fields (Ostenfeld 1924).

The fell-field occupies the greater part of the ice-bare country, being found on the outer islands at the level of the sea and on the highest snow-bare peaks and plateaux, in the extreme south no less than in the extreme north, but the farther north the poorer and more stunted. In North Greenland the fell-field is almost the only plant formation; other formations merely occur in especially favoured places, but without exception they are of very limited extent. With the fell-field belong the *nunataqs*, which have been visited by so many of the Danish travellers. Of these Garde writes: "No living thing, either of the vegetable or of the animal world, did we see on these peaks, nor did we discover even the poorest species of lichens." Jensen and Kornerup, on the other hand, in 1878, found 26 species of phanerogams, "stunted and creeping," as well as dense tufts of *Oxyria* and thick moss-cushions on nunataqs, 1350 m above the sea and 75 km from the edge of the inland ice. From the Upernivik District Ryder pictures nunataqs submerged in the inland ice, because their dark rocky ground absorbed so much heat that the melting-off could keep pace with the advance of the ice; here the vegetation began a few yards from the margin of the ice, and in it there were willow-trunks about an inch thick, only 7½ m from the inland ice. On the nunataqs of South Greenland 54 species of phanerogams were found (Kornerup).

2. *Dwarf-shrub-heath.*

After fell-field this is the most common formation. It deviates from fell-field in that it has a continuous vegetation, the greater part of which consists of dwarf shrubs. It is not the substratum but the plants which convey to the Greenland heath the same solemn dark-brown tinge which we find in our

own heaths. The dwarf shrubs which give the tone to the plant growth are the same as occur in the fell-field, but here they frequently form a close carpet of 25 to 30 centimetres in height, with interlaced branches. Herbs and grasses are found interspersed and a sub-vegetation consisting of mosses and lichens. In the less favourable places many of the shrubs are of espalier-shape, in particular dwarf birches, willows and junipers. Naturally there are also more open spaces, the species of which are herbaceous plants, but more especially mosses and lichens.

The dwarf-shrub-heath presupposes better conditions, especially more shelter. In winter it requires an unbroken cover of snow, which must not be so thick but that it may melt away rather quickly in springtime. The ground must be somewhat sloping (at least 5 to 7°) so that the water may run off easily, and the soil become dry and warm. Water rich in oxygene and nutritive substances makes the growth more luxuriant. On quite level ground it does not thrive so well, particularly if there is stagnant water, and it is also rarer on steeper slopes. Exposure does not seem to be of great importance. On a substratum of bare rock dwarf-shrub-heath cannot form, but the greater the amount of weathered particles contained in it, and the more thoroughly it has been prepared with mosses and lichens, the more luxuriant it becomes. Still, there is often only a short distance down to the rocky sub-stratum.

The nature of the ground and other conditions determine the size of the area over which the dwarf shrub-heath is able to prevail. It is frequently broken by fell-field or other formations, as for instance moors. According as the substratum becomes more level, the cover also becomes more uniform, particularly in places where *Empetrum* dominates.

However, not all dwarf shrubs are equally suited to make a continuous covering. In central Greenland the chief species forming associations are: *Empetrum*, which is mostly found in dry places, open to the wind; *Vaccinium uliginosum*, dwarf birch (*Betula nana*) and the willow *Salix glauca*. In South Greenland *Betula glaudulosa* replaces *B. nana*, and here *Cassiope tetragona* is wanting (it is not found south of lat. 64° N.), whereas in the north *Cassiope* becomes very common, perhaps more common than *Empetrum*.

Of these species special associations are formed: *Empetreta*, *Betuleta nanae*, *Vaccinieta uliginosi* (fig. 1) and *Cassiopeta tetragonae*. On the other hand, *Rhododendron lapponicum*, *Diapensia lapponica*, *Loiseleuria*, the *Ledum* species and the other occurring dwarf bushes cannot form continuous communities, because, unlike the former, they have not a prostrate growth or travelling shoots. They are more or less tufted or cushion-shaped. To the rare species belong *Arctostaphylos alpina* and *Uva ursi*, *Vaccinium Vitis idæa* and *Linnæa borealis*.

The herbs or grasses which fill the spaces between the shrubs are largely the same as those of the fell-field—all adapted to drought and frequently with rather striking flowers.

Fig. 1. Vaccinium heath in the Angmagssalik district with Polysgonum viviparum and Carex rigida (Chr. Kruuse).
The pencil is 13 cm high.

Of vascular cryptogams may be mentioned the ferns *Woodsia ilvensis* and *Aspidium fragrans*, and, finally, there is frequently a rather luxuriant sub-vegetation consisting of lichens and mosses. There are places in the dwarf-shrub-heath, where the latter practically dominate and form small spots of lichen or moss-heath.

The sub-vegetation of the dwarf-shrub-heath resembles that of North Europian heaths (Calluneta), in that it gradually, in many places, merges into peat-like, dim and presumably sour humus, composed of the many fallen leaves and other particles of plants. Together with the dwarf shrubs themselves this makes the principal fuel of the Eskimo population. In this "raw humus" there are a number of fungi, among others larger *Agaricaceae*. Although earthworms have not been found in it, insects and spiders have, and in summer it is the scene of considerable animal life.

On Disko Island Porsild (1902) studied the genesis of the dwarf shrub-heath, finding the following succession on stony ground:

1) crustaceous lichens on a rocky substratum,
2) shrub-lichens,
3) low xerophilous shrubs,
4) dense, taller mosses,
5) low dwarf-shrubs and herbs, which may be succeeded by a taller shrub or grass growth, or by moss and swamps. On loose soil the succession is different, *viz.* from moraine to fell-field, then to herb-field or heath and from naked dune to dune vegetation and then to heath.

Dwarf shrub-heath is found all over South-west Greenland, from the sea and, in favourable places, up to levels of at least 300—400 m where it rivals with the fell-field; the worse conditions grow the poorer it gets, and the more it passes over into fell-field. At Upernivik it is, for instance, found close to the sea, in particular on the slopes facing south. In the more favourable places of the lowland it often dominates entirely.

Lichen and *moss-heath* may be mentioned in connection with dwarf shrub-heath, being in a way a kind of tundra, the sub-vegetation of the dwarf shrub-heath developing into an independent growth.

In the higher and lower fell-field there are many mosses and lichens, though they do not form such wide-spread communities consisting of shrub-lichens as those which clothe the mountain ridges of the interior of Norway, as for instance along the Østerdal, with a dense, tall, soft, grey carpet, neither are the mosses known to form extensive communities, such as the tundras of North Europe. This is undoubtedly due to the dry air and the wind in the plateau of the interior of Greenland. The only places in middle West Greenland, where shrub-lichens are at all common, are the skerry-fence and the outer coast, but then the climate in these localities is damper and more foggy. Of shrub-lichens it is more particularly Icelandic lichen

(*Cetraria islandica*) *C. nivalis*, reindeer lichen (*Cladonia rangiferina*) and other *Cladoniae* and *Stereocaulon* which prevail.

In the outer coast land there are depressions in the soil which are entirely filled with shrub-lichens, sparsely admixed with phanerogams (*Empetrum*, willow, etc.) and a number of mosses (species of *Racomitrium*, *Polytrichum*, etc.).

A closer examination will undoubtedly prove a similar difference in the sensibility of the lichen species and their resulting distribution, as the one demonstrated by Kihlman on the strength of researches made in Lappland.

The lichen-heath seems to be richest and most general in South Greenland, where the climate in the interior parts is not only moist, but also warmer. In places which were less exposed to wind Rosenvinge found large tracts covered by light grey carpets of matted lichens. Lichen-heath probably also occurs farther north in the interiors of the fiords, as for instance at Godthaabs Fiord, and in the inner tracts to the east of the coastal mountains, which were traversed by Nordenskiöld (see above p. 296).

3. *Copses.*

These are communities consisting of upright shrubs, tall or of medium height, with a sub-vegetation of perennials, grasses, mosses or lichens.

Some species of shrubs never form copses, but are to be found interspersed among the latter, as for instance junipers (*Juniperus communis*) which very frequently assume a decumbent form, the prostrate trunks being covered by mosses, while fresh, green branches stand out erect a metre or more above the ground. *Sorbus americana*, the northern limit of which is the Fiskenæsset District, and which becomes a straight little tree of about 2 m in height (Hartz found specimens of up to 3.5 m) with trunks a couple of centimetres thick, is greatly appreciated, because of the element of variation introduced into the monotony of the copses by its beautiful foliage, its brightly coloured flowers and fruits. Also the alder (*Alnus ovata*), which occurs from Arsuk to Holsteinsborg, is represented, either growing singly or in small groups, interspersed with the willow and birch copses. It attains a height of 1 to 2 m.

The lowest copses are composed of dwarf birches (*Betula nana*). In the dwarf-shrub-heath they are mostly espalier-shaped, but under favourable conditions, where there is less wind, they become of upright growth and form low copses, which attain a height of about 1 m. The soil is rather dry and generally covered by grasses, brownish mosses and light lichens. According to Rosenvinge *Betula glandulosa* does not form copses in southern Greenland.

The copse formations proper are willow copses and large-leaved birch copses.

Willow copses are first and foremost composed of *Salix glauca*, which occurs from the extreme south to the extreme north; and to a lesser degree, in the northern region, of *Salix Groenlandica*, which is perhaps identical with *Salix arctica*. Descriptions of these copses are given by Rosenvinge and Hartz, from South Greenland; by Porsild, Kruuse and Hartz from more northerly regions.

The essential conditions for the development of luxuriant tall willow copses are a certain warmth and humidity, a cover of snow during the winter, shelter against the wind and, preferably, throughout the whole period of growth, a regular supply of water, rich in oxygene and nutritive substances and slightly heated by the sun. They are consequently to be found in places sheltered against the wind, such as in valleys, hollows between mountains where rivulets run down, on sunny mountain slopes facing south, or at the foot of mountains, where humus may gather, and where the soil is kept moist by the water oozing down from the heights. The best soil is gravel or sand composed of loose particles, due to weathering. The farther removed from the sea, the taller and more luxuriant they may grow.

In winter the lower willow copses are covered with snow, and they probably always become free of snow at an early period. The willow copses attain a height of up to 2,5 m.

The finest copses occur in the interior fiord valleys of the Julianehaab District. In several of the deep fiords all slopes are covered by them when not too steep or consisting of loose, continually sliding gravel and rubble. These copses are interspersed with birch (*Betula odorata*), *Alnus* and *Sorbus* while tall, light-green ferns make a pleasing variation. As to the ages of these copses Rosenvinge gives a number of particulars. Copse shrubs were not nearly as old as isolated individuals (thus shrubs of more than 80 years occurred), but the annual rings were widest in the former. According to Rosenvinge this difference is perhaps only apparent, seeing that in the case of copse shrubs attention was chiefly directed towards the branches, whereas in the case of those growing on the rocks it was the main trunk which was subjected to investigation.

Even as high up as on the south side of Disko there are fairly large copses, particularly in the valleys. Also in this place the shrubs become up to 2 m in height.

The most northerly real copse occurs at Orpik (lat. 72° 30′ N.) at the head of Laksefiord, near Upernivik (fig. 2). It has been described and pictured in detail by Porsild and is as much as 2 m in height. In East Greenland willow copses are found at Scoresby Sound.

In less favourable places, as for instance in the islands of the skerry fence and high up in the mountains, the willow copses become low, 30 to 50 cm in height, and the individual shrubs more or less espalier-shaped, though they are perhaps as much as 3 to 3.5 m in length; one can no longer walk under them, but only on them, and there is hardly any sub-vegetation.

In the tall luxuriant copses there are frequently layers of mould, many centimetres thick with earthworms (species of *Enchytræus*), insects and snails (*Vitrina Angelica*) and a rich undergrowth. The nature of the latter depends upon the shade. In the very dense copses there are hardly any phanerogams, but at most a brownish moss carpet and most frequently a black-brown mould humus without plants. In the less dense there are a number of phanerogams and vascular cryptogams such as *Equiseta* and tall, light-green

Fig. 2. The northermost willowcopse in Greenland (Porsild).
The boy is sitting down.

ferns, taller or lower perennials, and swelling, fresh green moss cushions round the rivers; for instance, at Godhavn I saw specimens a foot in height of *Alchimilla* and *Taraxacum*, yellow-flowered *Potentillae*, *Arabis Alpina* with the shining white flowers, broad-leaved *Luzula parviflora*, *Poa pratensis* and other grasses, three species of orchids and many other herbs interspersed with this fresh and green luxuriant vegetation. Also the quan (*Archangelica officinalis*) occurred. It is a large, umbelliferous plant, which may attain a height of 2 m and with shoots of the thickness of an arm; as is well known, it is by the Ekimos considered a great delicacy. Sometimes it is found in great quantities round the water courses in the copses, but it hardly extends farther than nearly lat. 70° N., on the east side of Disko Island; here it grows at altitudes of 500 to 600 m above sea-level. Under the quans there are, according to Porsild, umbrophilous mosses, *Jungermanniae*, foliose lichens, and large fungi (*Clavaria*, *Peziza* and others). In this region the existence of the quans is conditioned by hot springs.

Finally, there are also very open and dry willow copses, the shrubs of which are scattered and low (prostrate) as in the outer land of South Greenland. These form a transition to the dwarf shrub-heaths.

The herbaceous sub-vegetation is very different according to the latitude as well as the distance from the sea. In South Greenland there are a number of characteristic species, such as *Achillea millefolium*, several species of *Hieracium*, etc.

Between lat. 64 and 67° N. there are also many species, whereas the num-

Fig. 3. Birch copse in the Kingua Valley in the Tassermiut Fiord (O. Bendixen).

ber of additional ones north of 67° is very small. At the Vajgat many of the species of the southern latitudes are lacking.

The herbs are large-leaved and fresh-green. According to Rosenvinge there are copses with such abundance of grasses that the undergrowth is rather a grass carpet with interspersed herbs.

Also the mosses may occur in rather large communities along the banks of water courses where there is a constant flow of water, as for instance the yellowish-green *Philonotis fontana*.

Copses of large-leaved *birches* (*Betula odorata* and *tortuosa*) only occur round the long fiords of the Julianehaab District (fig. 3) where the summer is warmer than elsewhere in Greenland. The precipitation in this part of Greenland is very large: thus, Ivigtût has an average yearly precipitation of 114.5 cm, or twice the precipitation of Godthaab and 5 to 6 times that of Upernivik. Inland, however, there is in all probability a much smaller amount of precipitation, and here the birch copses represent the birch region of the Scandinavian Peninsula, just as the willow copses represent the willow region. In this locality, as in Iceland, Scandinavia and northern

Russia, including Kola, birch forms the tree limit, while east of Kola the tree limit is formed by conifers.

For our knowledge of birch copses we are indebted to Rosenvinge and Hartz. These copses, which are the most exacting of the formations of Greenland, shelter between the dark coastal mountains, so poor in vegetation, and the ice which covers the interior. They only extend as far as lat. 62° N. and in a few places may almost assume the character of a wood.

Sometimes they are pure associations of *Betula odorata*, but frequently willow, alder, *Sorbus* or juniper are interspersed with the birches. The general aspect is like that of the willow copses, but they sometimes may grow higher and, in particularly sheltered valleys, individual birches may attain to the height of actual trees. However, it is nearly always so that there are short, gnarled and thick parts of trunks, which creep along the ground and then rise in the shape of a bow with thick trunks. According to Hartz the height of the latter may be as much as 6 m and their circumference 2 to 3 cm. Rosenvinge expressly states that he has never seen trees with a single upright trunk. He puts the ages of the oldest specimens at a hundred years.

Birch copses are found in drier soil than willow copses, but they do not extend so far towards the sea. They require more sunlight and heat than the willow copses, and slopes facing north are frequently overgrown—not with birch copses, but with heath. They are lacking in all level areas which are not particularly sheltered against the desiccating agency of the southeast wind.

The sub-vegetation differs somewhat according to the nature of the soil. Rosenvinge states that it is frequently a grass growth, consisting of *Anthoxanthum odoratum, Deschampsia flexuosa*, as well as other grasses, such as *Festuca rubra, F. duriuscula, Calamagrostis phragmitoides*, etc. or, in other words, a rather dry soil, as the nature of these species must be supposed to be the same here as in Denmark.

In other cases the formation is intermixed with so many lichens that it may be called a lichen-grass-field, and then again in other cases a lichen-heath.

Naturally large-flowered herbs and vascular cryptogams are interspersed into the grass-fields. Among the latter are a number of species characteristic of South Greenland, as for instance *Rubus saxatilis*, several *Hieracieæ* and others.

According to Rosenvinge the Julianehaab District has 33 characteristic species.

4. *Herb-field and Grass-field.*

In willow and birch copses permeable to light the sub-vegetation is as a rule richest and densest, and when the shrubs cease, the sub-vegetation

frequently remains; according to the nature of the substratum it then forms independent herb-field or grass-field.

The perennials, herbs and grasses, occur in many places outside the copses, as for instance in talus and in shady hollows or depressions, but apart from that, they form continuous turf-carpets, which in some places chiefly consist of large-flowered dicatyledonous plants, rich in flowers, while in other places the grasses dominate. It is the former formation, which I have called herb-field, and which almost exclusively occurs on a sloping, or even acutely sloping substratum, in particular gravelled mountain sides facing south, preferably in such places where the soil is constantly moistened by melting water oożing down, or along the many little water courses rushing down the mountains. The snow-cover forms early and melts early. The soil is rich in well-ventilated mould with earthworms *(Enchytreus)*. The flora is extremely variegated. In a valley near Sukkertoppen I noted in the course of an hour no less than about 60 vascular plants, which with a few exceptions must be considered as belonging to the undergrowth of copses, and these were greatly intermixed, so that no single species predominated.

Grass-field. On more level ground or less steep mountain sides the grasses are sometimes found to prevail over the herbs. There is some difference between the former. On Disko Island there are, according to Porsild, open and dry fields, the vegetation of which consists of *Carex nardina*, *Elyna*, *Poa glauca;* further, of mesophile grass-fields of small extent, and, finally, of meadows covered with *Calamagrastis neglecta*, *Glyceria*, *Carices*, *Eriphorum*, *Dupontia*, *Pedicularis*, *Potentilla*, etc. as well as *Lycopodium annotinum* var. *alpinum* and others. Also, scattered and stunted specimens of dwarf shrubs are to be met with.

In South Greenland there are areas covered with a tall grass vegetation. Giesecke mentions grass-fields at Igaliko, where the grass reaches "halfway up to the waist," and Kornerup writes: "Over long stretches one may wade in tall grass, reaching as high as the hips. So the grass can be cut for hay, and cattle is kept (cows, sheep and goats). The haying lasts from the beginning of July till far into the month of August." It is more particularly species of *Calamagrastis* which compose these tall grass-fields, but, besides, there are others, as for instance *Deschampsia flexuosa*, *Anthoxanthum odoratum*, species of *Festuca*, *Poa*, *Phleum*, *Agrostis*, *Trisetum*, *Agropyrum* (*A. violaceum*), *Luzula*. Large-flowered herbs are interspersed.

Manured soil. The most luxuriant herbaceous and grass vegetation is to be found in places where the soil in some way has been mixed with animal manure, so that black, fat, rich mould has been able to form. It is always only over small areas, and always near the sea or close to rivers. Such places are:

1) The *refuse heaps* near the dwelling places of the Greenlanders, whether

summer or winter dwellings, where all kinds of refuse from hunting or meals, as well as human and animal excrements are left. The soil becomes thoroughly trampled and hard, but it remains moist because the water oozes down slowly; at the time of the melting of the snow, as well as in rainy weather, it may be muddy, and in the water pools there frequently live many *Cyanophyceae* and a few phanerogams (*Montia, Ranunculus hyperboreus*).

Even when seen from afar, these patches stand out by their fresh, green colour, which is due to 0,3 to 0.5 m tall and luxuriant herbs and grasses, in particular *Alopecurus alpinus, Cerastium alpinum, Poa pratensis, Stellaria longipes, Catabrosa algida, Polygonum viviparum, Glyceria distans, Saxifraga cornua, Cochlearia* and several other species.

South Greenland, in its turn, has some other species, such as: *Rumex acetosa, Matricaria inodora, phæocephala.*

At the settlements one may also find a not inconsiderable amount of species which have been carried there in more recent years.

2) *Bird cliffs.* Under the perpendicular coastal mountains, on the ledges and shelves of which sea birds brood in thousands and myriads, a good deal of manure is deposited, whitening the surface of the cliffs. In the talus or elsewhere at the foot of the mountains a community of green plants develops, tall and luxuriant like those of the refuse heaps, and partly consisting of the same species.

3) *Gull mounds.* Finally, within the skerry fence there are many small islands, where eiderduck, gulls, terns, black guillemots and other sea-birds brood or settle for a rest. As the gulls settle on the highest peaks, small mounds form here, chiefly consisting of their excrements; in such places a soil may form, so rich in particles of plants that it can be used as fuel, a kind of hard, black peat, about one foot in thickness.

5. *Fresh Waters.*

Fresh waters are partly running (rivers, rivulets), partly stagnant (lakes, ponds, water-pools). In the preceding some remarks have been made of the vegetation immediately surrounding the beds of rivers: it is fresh-green, frequently consisting of thick, green moss-cushions, with interspersed phanerogams, among which broad-leaved species of *Alchemilla, Pedicularis, Tofieldia, Juncus, Ranunculus* and others. In the cold mountain rivulets also occurs the characteristic, slimy, greenish *Hydrurus foetidus.* As to the plants growing in the water of the river-beds only little is to be said. There are no taller plants, but partly green algæ attached to stones and the rocky soil, partly species of Hydrurus and Limnobium, the latter very characteristic of water falls.

In the irregular channels, which in grass-field and dwarf-shrub-heath may be formed by the water running down from more elevated places

within the melting period, the small greyish liver-moss, *Anthelia julacea*, is of frequent occurrence. When the channels later on have gone dry, it is frequently seen together with *Salix herbacea*.

Special mention should be made of the *hot springs*, which are known from many places in Greenland. Porsild has given a list of the rather extensive literature dealing with this subject (see also Warming, 1887). "Hot" the springs are called, also when they are running in winter, sometimes under a cover of ice.

The springs on Disko have, in summer, a temperature of 0 to 3°, being intermixed with great quantities of melting water. In the winter the temperature is 8 to 17°. The warmest spring known is found in South Greenland, lat. 60° 30′ N. The water welling up has a temperature of 40°. A fog-bank is always hovering over it, as over so many Icelandic hot springs. In the area surrounding it, up to 60 m in extent, there is a vegetation of more than 30 species of phanerogams, which otherwise only live in the sheltered fiord-valleys.

In the water basins there is frequently a rich vegetation of *Cyanophyceae*, and clumps of *Nostoc* are seen floating on the surface. Round the heads of springs there is generally a luxuriant growth of mosses and algæ.

Stagnant waters. Greenland abounds in such, great and small, and according to Nordenskiöld, the lowland, situated between the coastal mountains and the inland ice is perhaps the country in the world which is richest in lakes. There is a great difference in the vegetation of the latter, according to size, depth and situation, and according as they are perpetual or go dry in summer; also the temperature of the water is of great significance. Those which are situated in the most unfavourable localities farthest north, high up in the mountains or close to the sea, often seem to be entirely devoid of plant growth, in particular the large and deep ones. The clear water washes against the naked and cold cliffs of the banks; through it one sees quite distinctly the naked, uncovered sand and stones of the bottom, nor is there any trace of animal life.

In other smaller water basins there is frequently a considerable vegetation. One sometimes sees water-mosses (species of *Hypnum*, *Harpidium*) covering the substratum with a fresh-green carpet at a very considerable depth; on Disko Island Porsild saw large quantities of *Harpidium fluitans* and other species at depths of 2 m. Furthermore, a *Characea* (*Nitella translucens*) and the rosettes of *Isoetes echinospora* occur. A number of other algæ, among which *Desmidiaceae* and *Nostoc commune*, have also been found. Phanerogams occur in fairly large numbers, some forming associations, as, for instance. *Hippuris vulgaris*, *Batrachium confervoides*, *Ranunculus hyperboreus* and *reptans*, *Myriophyllum alternifolium* and *spicatum*, *Callitriche auctumnalis*, *verna* and *hamulata*, *Utricularia minor* and *ochroleuca*, *Montia lamprosperma*.

Menyanthes trifoliata, Potamogeton filiformis and *marinus, mucronatus, pusillus, rufescens, Subularia aquatica, Saxifragia rivularis, Heleocharis auriculus, Sparganium hyperboreum.*

As it will appear entire families are absent, as *Alismaceae, Hydrocharidaceae, Lemnaceae, Nynphæaceae.* There are no water plants, characteristic of the arctic zone, but several species from the temperate zone extend far towards the north, first and foremost *Ranunculus hyperboreus* and then *Hippuris.* It is the short vegetation period which sets the limit to their distribution and makes most of them sterile. The *Potamogeton* species have winter buds, *Hippuris* and *Batrachium*, however, fructify rather frequently.

Shallow ponds and pools, the waters of which are easily heated by the sun, have the richest vegetation here. *Ranunculus hyperboreus*, for instance, occurs in the same manner as *Batrachium* in Denmark, covering the surface with long floating shoots.

6. *Meadows and Moors.*

In the large river valleys and at the river deltas there are large alluvial plains, composed of the finer mineral particles, sand and clay with small stones, washed down in spring time from the mountains by glacier and melting water. According to the fineness and weight of the particles the latter are distributed over the country.

In the periods of the melting of the snow many of these plains are inundated; as summer progresses, their bottom may sometimes, according to local conditions and the height above the ground-water, be very rich in water, bearing moor or meadow growths, or they may be dried-out wastes, the plant growth of which suggests that of fell-field.

There are also entirely sterile plains with plants scattered here and there, because the strongly flowing and rushing waters of the spring time tear up the plants and wash them away. The substratum may vary greatly in the same valley, the plant-growth depending not only upon the nature of the soil but also upon its age, upon the frequency of the inundations by high-water and upon the duration of these inundations. There are plains almost devoid of vegetation, for instance at Itivneq (Holsteinsborg).

Hartz describes tracts at Sydost Bugt, where a broad river debouches. Frequently low clay banks, entirely devoid of plant growth or covered with dwarf-shrub-heath stand out in the middle of the current, and in some places a salt meadow may be on the point of forming. At Lerbugt (Egedesminde) he encountered a scattered, but rather characteristic plant growth which was not continuous, but consisted of tufted plants at a considerable distance from one another.

Porsild mentions moist clayey plains on Disko Island with cushions of moss and other plants, forming a network over the otherwise bare clay surface.

Vanhöffen speaks of moist meadows with a dense luxuriant vegetation consisting of *Juncus biglumis* and *triglumis*, two species of *Eriphorlum*, *Elyna Bellardi* and grasses up to half a metre in height. These "meadows" should perhaps rather be considered as moors, being of very common occurrence in the lowland of the level, moist places, which partly surround water courses or lakes and ponds, and partly are to be found over fell-field and dwarf shrub-heath in hollows where the melting water remains for a long time, sometimes only covering areas of a few square metres.

The soil of moors is muddy and brown, probably always sour. For reasons which have hitherto not been cleared up, their vegetation varies, and in particular a distinction must be made between carex moors and moss moors. The duration of the cover of snow is probably the decisive factor, seeing that the carices must have sufficient time in order to develop (Porsild).

Carex moors are chiefly composed of various species of *Carex* and other genera of the same family. The substratum may be quite densely covered, in particular where mosses fill the interspaces between the phanerogams, so that a really continuous vegetation is formed. In the extremely moist places it is *Eriphorum angustifolium* and *Scheuchzeri* which constitute the main part of the latter and are the pioneers in the drying-up of the water basin. In other places it is the *Carex-genus* and *Scirpus cæspitosus* which is the chief constituent, interspersed with other, but more large-flowered species (the genera *Cardamine*, *Equisetum*, *Pedicularis*, *Pinguicula*, *Ranunculus*, *Saxifraga* and others); also small dwarf shrubs such as *Salix groenlandica*, *Empetrum*, *Ledum* and *Betula nana*.

Kruuse distinguishes between "level" moors, which must be like those mentioned above, and "tuft moors," where cæspitose *Carices* form the chief constituent. On these tufts, which are about one-third of a metre in height, there is a somewhat deviating soil where dwarf-shrubs occur, whereas between the tufts there are shallow, frequently net-like channels which are due to solifluction and which in the early melting period are filled with water, and later on are dry with a vegetation consisting of the grey liver-moss (*Anthelia julacea*) together with *Salix groenlandica*. Such moors form the transition to dwarf shrub-heath.

As in Denmark moors are among the plant formations which develop late in spring, because the soil is so cold, most frequently frozen to a shallow depth; consequently, they still are greyish and withered when the season is already far advanced in the other formations.

Moss-moors. In the *Carex*-moors the interspaces between the grass-like plants are often more or less filled with mosses, which in many cases become the prevailing growth form, while the phanerogams disappear. The chief constituents of such formations are the yellowish-green *Aulacomnia*, the strong brownish *Polytricha* and the whitish or pink *Sphagna;* in one locality

the one, in another the other prevails, probably depending upon the degree of humidity of the soil. The species frequently form almost pure associations and are not so intermixed as in the moss-heath; so, for instance, *Hypnum turgescens* and other species frequently cover large tracts. On mountain sides which face north and in summer are moistened by melting water, there also occur moss-fields of other species.

As a rule phanerogams are intermixed with the moss-vegetation, in particular dwarf birch, *Empetrum*, *Ledum*, species of *Ranunculus*, *Saxifraga*, *Carex* and others which prefer, or are able to thrive in a moist soil. According to Porsild there are in such places also many *Agaricaceae*, particularly in moss-moors and in moist spots in the heaths, and during moist and not too cold summers they may occur in very large quantities.

The conditions for the formation of moss-moors are, as far as is known, more especially that the soil should be a moist clayey or sandy plain, perhaps periodically inundated; the water is rather stagnant and in all probability also contains acids. The soil is moister than in the moss-heath, but not so moist as in the *Carex*-moors, and the snow melts at a later period than in the moss-heath.

Moss-moor consisting of peat mosses (*Sphagnum*) is probably the rarest type, and it evidently becomes rarer and rarer the farther north one gets. This undoubtedly has some bearing upon the fact that the atmospheric humidity, without which peat-moors do not thrive, decreases strongly in a northern direction.

But also other mosses may produce peat-moor, which has been found all along the coast. Hartz mentions a "considerable peat moor" north of Frederikshaab: it is said to contain the best peat of Greenland, and to be at least two-thirds of a metre deep. It consists of *Hypna* and *Sphagna*. Giesecke mentions peat from Godthaab and Holsteinsborg, 15 to 30 cm in thickness. On a "peat island" at Egedesminde I found moss peat, resting on a rocky soil and up to one metre thick. The loose, swampy peat was produced from *Webera nutans*. Even at Cape York peat production takes place. Nathorst writes that some of the water basins are on the point of passing into peat-moor, which is almost exclusively formed of water mosses.

Shore Vegetation.

To conclude, mention should be made of the vegetation associated with the clay and sand plains exposed to saline water.

Where the coastal cliffs do not drop steeply down to the sea, so that their foot is clothed with the algal vegetation, mentioned on page 293, higher up with halophilous lichens and in the clefts with phanerogams and mosses, there is between these slopes and the sea a shore, the soil of which is *clayey* where most sheltered against the action of the waves, so that the finest

mineral particles can be deposited there, but *sandy* where there is less shelter, or *stony-gravelled*, where the waves beat most strongly against the shore. There are also places where *stony foreshores* are formed on the beach by the action of the waves.

Clay shores are to be found in the interiors of the calm inlets and on the sides of the river deltas which are sheltered from the coast currents. The soil consists of a fine greyish ooze, and in it a plant growth develops which bears a greater or smaller resemblance to that of the salt meadows of Denmark. In Greenland as well as in northern Europe the chief constituents of this vegetation is a species of the grass genus *Glyceria* (*G. vilfoides*). Its manner of growth is similar to that of *G. maritima* in Europe; with epigeous runners, which also resemble those of *G. maritima*, it covers the substratum, collecting and securing its constituent particles so as to form a dense low, green cover of interlaced shoots. Little by little the soil becomes higher and higher owing to the deposit of mud, and now also other species find a favourable habitat.

Together with *Glyceria* occurs its inseparable companion *Stellaria humifusa*, and later on also *Potentilla anserina*, *Plantago maritima* and *borealis*, *Konigia islandica*, *Equisetum arvense*, as well as several *Carices* (*C. glareosa*), *Glyceria distans*, etc. Below the latter there is a sub-vegetation of *Cyanophyceæ* and a few mosses.

In the Egedesminde District Berggreen observed the following succession or zonal formation: Nearest the sea *Glyceria vilfoides* reigned; it was succeeded by *Carex glareosa* and *Glyceria distans*, then by *Elymus arenarius*, accompanied by *Plantago*, *Glyceria vaginata* and *Cochlearia fenestrata*.

Salt meadows are found all the way from South Greenland as far as Upernivik, in both localities mentioned by Rosenvinge, but hardly to any great extent. By the whole of their appearance and development these salt meadows remind us of those of northern Europe, also in that holes and pools of brackish water form in them, the latter bearing a saprophytic vegetation.

Shore sand consists of white or black sand and always has an open vegetation, which also from the point of view of the flora, bears a great resemblance to that of northern Europe. First and foremost there are *Honckenya peploides* and *Elymnus arenarius*, then a number of *Carices* and grasses (*Carex glareosa*, *incurva* and *hyperborea*, *Agropyrum*, *Festuca rubra* and *ovina*) and a number of other phanerogams such as *Mertensia maritima*, *Stellaria humifusa*, and in South Greenland *Haloscias scoticum* and *Lathyrus maritimus*.

When the sand has become firmer and the distance from the sea greater, other less characteristically and pronouncedly saline plants occur.

In Greenland as elsewhere there seems to be, according to the accounts of travellers, a vegetation of sand-algæ and Hock sand, rich in iron sulphide

and bacteria; thus Kruuse mentions a black, ill-smelling soil within the Egedesminde skerry-fence.

Dunes. In several places along the coast small dunes are formed on the sand plains, as along the Vaigat, at Holsteinsborg, Frederikshaab, iceblink and other localities. *Elymnus arenarius* var. *villosa* is a common dune grass, "the stateliest grass of Greenland."

Otherwise dunes, in Greenland no more than in other countries, are limited to the shore, but may form everywhere in the interior where there is a sandy soil, which is dried up and exposed to strong winds or storms.

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THE FAUNA OF GREENLAND

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I. MAMMALS.

It may be taken for granted that there were no land mammals in Greenland during the ice age, and that those which are now to be met with there have immigrated at a later period. As Greenland is situated far from other countries, except towards the north-west, the immigration must have taken place from high-arctic North America across the narrow sounds which are covered by ice during the greater part of the year and here, as it were, form a bridge. Therefore, the land mammals of Greenland, from north to south, are high-arctic forms, which all occur in northernmost America, and this further supplies the explanation of the poverty of this part of the fauna, which only comprises seven species in all, *viz.* musk-ox, reindeer, ermine, polar wolf, polar fox, the collared lemming and the polar hare.

The *musk-ox* (*Ovibos moschatus* Zimm.) is met with in small, scattered herds, nowadays only on the north and north-easterly coast, from Cape May on the north coast (lat. 82° 27′ N.) to Scoresby Sound on the east coast. In former times it was more widely distributed; as late as 1871—72 the "Polaris" Expedition encountered several small herds in the region round Thank-God Harbour on the north coast (lat. 81° 38′ N.), but there it seems to be exterminated, for in 1917 the Second Thule Expedition looked for it in vain in those parts. The musk-ox has even lived right down to Cape York; at Thule, for instance, its bones are common in kitchen middens, but in these regions it has now been exterminated by the Eskimos long since. Upon the whole the musk-ox in Greenland has been subject to very reckless treatment, partly by the hunting of the Eskimos and arctic expeditions, partly by the attempts at catching the few calves for zoological gardens or the parks of the rich, in the course of which attempts whole herds of older animals have been killed.

The *reindeer* (*Rangifer tarandus* L.) which generally occurs in herds has,

in former times, been distributed over the whole of the outer land of Greenland, the north coast only excepted, but is now greatly limited in its occurrence.

From the most southerly part of the west coast where the reindeer occurred frequently, even as late as the end of the 18th century, it disappeared during the early half of the 19th century; the region near Narssalik, south of Frederikshaab, is the most southerly place in West Greenland where reindeer now occur. From the northern part of the west coast, the Thule District, where reindeer formerly occurred in great numbers, at least as far as Rensselaer Bay (lat. 78° 40′ N.), they have now practically disappeared, their distribution along the west coast at the present time being from the southern part of the Upernivik District to Sermiligârssuk Fiord in the southern Frederikshaab District; on Disko Island, however, the reindeer is entirely lacking. It is generally thought that this decline or extermination of the reindeer on the west coast is due to reckless hunting [1], and this is also thought to be the cause of the fluctuation in the number of animals within the areas where the reindeer still holds its ground. Of most frequent occurrence is the reindeer in Central West Greenland, where the outer land is broadest and the conditions for its existence particularly good.

On the southern part of the east coast the reindeer no longer occurs; in former times it lived at Angmagssalik, but now it is exterminated. Also on the stretch from Cape Dalton to Cape Brewster, the reindeer has disappeared during the last decades.

As to the northern part of the east coast the Ryder Expedition in 1891—92 encountered reindeer with comparative frequency in the region round Scoresby Sound; in 1899 Nathorst only saw a few herds, and in 1924—25 Alwin Pedersen found no other traces of reindeer than old cast-off antlers. The "Danmark" Expedition, which in 1906—08 investigated the northern part of the east coast, found innumerable traces (cast-off antlers and excrements) of the former occurrence of reindeer in great numbers, as far north as Holm Land (lat. 80° 24′ N.), but now they have entirely disappeared. The same observation has been made, during later years, by Norwegian hunters and by the hunters at the stations of the East Greenland Company. These extensive northern regions are so rarely visited by man that the total extermination of the reindeer can hardly be attributed to this cause. It seems more likely to suppose, as Nathorst does, that it is the polar wolf—which in former times was not seen in East Greenland, but rather suddenly made its appearance at the same time as the reindeer began to disappear—which has gradually exterminated the reindeer. There are, however, also

[1] It is calculated that in 1839 as many as 37,000 reindeer were shot in Greenland Even now 1000 animals are killed in the best hunting district, Sukkertoppen, in Godthaab about 600.

some who suppose that the reindeer has emigrated from the east coast of Greenland and across the inland ice has made its way to the west coast.

Still farther north, on the east coast at Cape Schmelk and on Adam Biering Land and Vildtland, the First Thule Expedition, in 1912, found numerous old reindeer antlers, but no living animals, although an energetic search was made for them.

Thus we arrive at the curious result that, although reindeer have lived

Fig. 1. Musk-ox (bull). After Knud Rasmussen.
In the process of casting its hair, when the loose wool is shed in large continuous patches.
North coast of Greenland, June 1917.

everywhere along the east coast of Greenland, they have disappeared entirely from that region in the course of the last decades.

The north coast of Greenland was investigated, in 1917, by the Second Thule Expedition which, however, found no trace whatsoever of reindeer.

Among land mammals the reindeer is the most important object of hunting to the Eskimos. The meat is eaten, and the fat is used, for instance, as cream for coffee, and the contents of the paunch are considered a special delicacy; the skins are used as underlayers on sleeping platforms and for sleeping bags and garments, the antlers for hunting implements, the sinews for thread, etc.

The reindeer hunters with their households set out in umiaqs, at the

end of June, and through the fiords they seek the great plateaux in the neighbourhood of the inland ice. They pitch their tents in the selected summer camp, from which the men go out hunting. During the latter part of August or the beginning of September the reindeer hunters generally return to their dwellings on the outer coast.

Although the profit is small as compared to that of an earlier period, these journeys are, however, still made by many, because the resulting open air life is considered by the native population one of their greatest pleasures.

In North Greenland reindeer hunting is in the main a winter occupation.

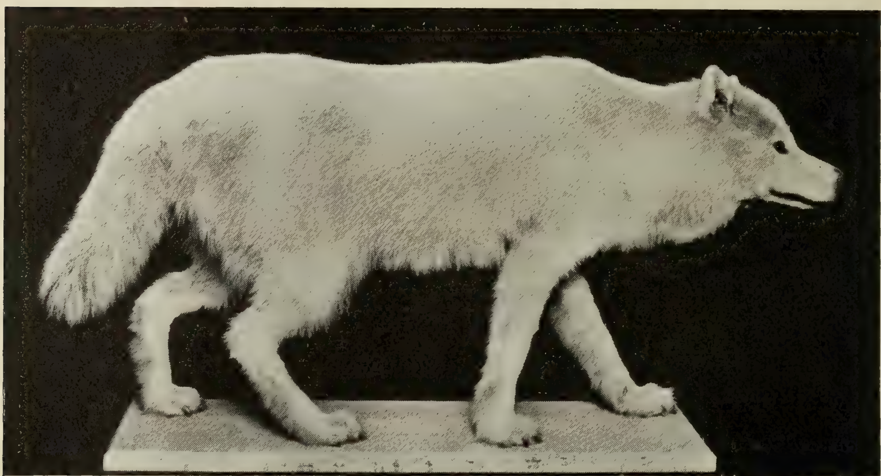

Fig. 2. Polar wolf.
From a stuffed specimen in the Zoological Museum af Copenhagen, shot near Umánaq in the winter 1868—69.

It should, in conclusion, be added that a regulation was issued in 1924 aiming at the preservation of the reindeer in South Greenland. By this regulation it was forbidden to shoot or catch reindeer and their calves in the period between May 20th and July 20th. Furthermore, no one at the time of the year when it is permitted to carry on reindeer hunting is allowed to kill more animals than that their meat and skin can be used on the spot, or taken home to the dwelling place where the hunter belongs.

The *ermine* (*Mustela erminea* L.) only occurs on the north coast and in the northern part of the east coast, as far as the region round Scoresby Sound; it may be considered as being of rather common occurrence, though it is nowhere to be found in any great number. It lives almost exclusively on lemmings, and consequently has entirely the same distribution.

The *polar wolf* (*Canis occidentalis* Rich. var. *albus* Sab.) has at the present time the same distribution as the musk-ox, in that it occurs on the north coast and the northern part of the east coast, as far as the region round Scoresby Sound.

It may be mentioned, as an event of rare occurrence, that in the winter 1868—69 two white wolves were seen together on the west coast, near the Ũmánaq settlement; one was shot, and its skin and skeleton are to be found in the Copenhagen Zoological Museum.

Even in the regions where the wolf now occurs, it is by no means frequent; it is only found scattered and is comparatively rarely seen. Before 1899, when Nathorst, on his expedition to northern East Greenland, observed

Fig. 3. Polar fox (blue fox). Photo by Alwin Pedersen, Cape Stewart, September, 1924.

several polar wolves, this animal had not been seen in those parts, although they had been visited by various travellers; this caused Nathorst to set forth the view that the wolf had only quite recently immigrated to the east coast from the north.

The *polar fox* (*Canis lagopus* L.) is of common occurrence along all the coasts of Greenland, being most numerous in western South Greenland at deep fiords which rarely freeze over in winter, less numerous on the north coast. The young, when quite small, are blue, but towards autumn some of them become white; the blue foxes are most numerous, but the proportion between blue and white varies much from one place to another; in the period 1920—24 an average of 2557 fox-skins were sent to Denmark from the settlements on the west coast, of which 1415 were blue and 1142 white. Within the colonized areas the fox is preserved in the period April 15th to October 1st.

Foxes are caught in traps, which are set on the beach with baits consisting of bits of fish or blubber; more rarely they are shot with rifles. The skins are sold to the Trading Company, but in the Thule District the Eskimos themselves use part of the skins for over-jackets and trousers for the women; in the same district the meat is eaten with great zest during the dark period, when the foxes are fat.

In 1913 a farm for the rational breeding of foxes was established at

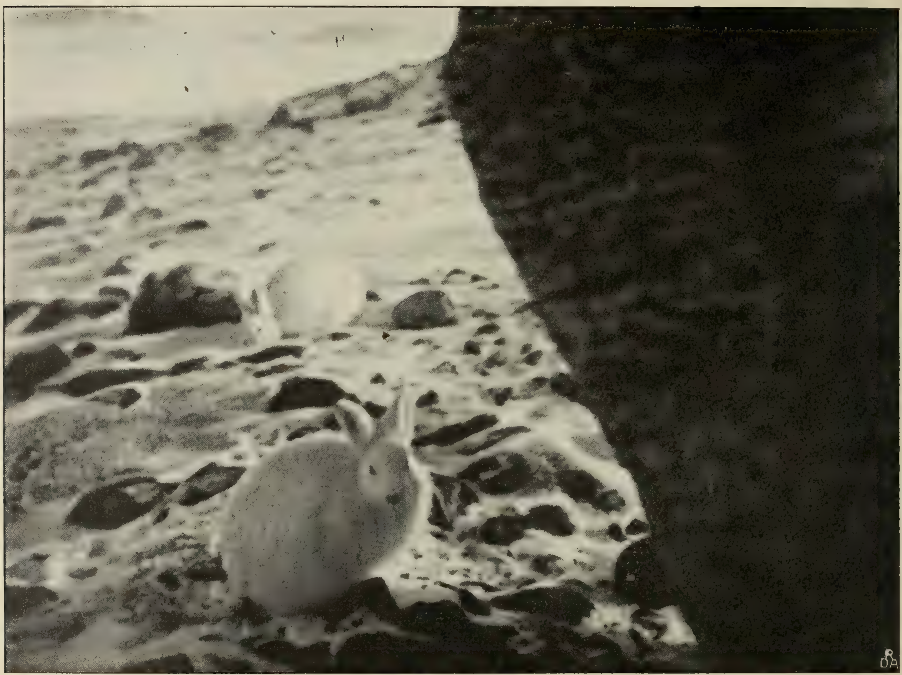

Fig. 4. Polar hares. After A. L. V. Manniche.
North-east Greenland. April 1907.

Godthaab. By the purchasing of young foxes, this farm has gradually acquired a rather large stock, and attempts are made at improving it by the selection of suitable breeding animals.

The *collared lemming* (*Myodes torquatus* Pall.) only occurs on the north coast and along the northern part of the east coast to the region of Scoresby Sound, but it is numerous and lives in flocks in places where there is profuse vegetation.

The *polar hare* (*Lepus variabilis* Pallas var. *glacialis* Leach) lives along all the coasts of Greenland, except in the southern part of the east coast (from Blosseville Coast to about lat. 60° 30′ N.), but in most places it is sparse and lives scattered. It is to be encountered on the rocks right down to the outer coast, but as a rule it mostly keeps to the interior of the country, where it prefers fairly steep slopes. From the point of view of hunting it

plays no very great part; the Greenlanders do not generally like its meat, but shoot it now and then in order to sell it to Europeans. In the Thule District it is caught in snares, which are set and tended by women and children; the skins are used for stockings.

In South Greenland it is forbidden to shoot hares in the period May 1st to August 15th.

The *polar bear* (*Ursus maritimus* L.) is, although it lives both on the earth and on the sea ice, most intimately associated with the sea, for here it seeks its principal food, first and foremost seals. It may be found along all the

Fig. 5. Polar bears on iceberg. Photo by George P. Putnam, 1926.

coasts of Greenland, mostly scattered, single, or in families, but in the southern part of the east coast and the greater part of the west coast it is only in the habit of appearing as a guest; with the pack ice it comes in winter and spring down the southern east coast, round Cape Farewell and up along the southern part of Julianehaab District; most rarely it appears on the west coast between Disko Bay and Julianehaab. Its chief resorts are the northern part of the west coast and the northern part of the east coast, but in the northernmost part of Greenland, or about the distance between Polaris Bay on the north coast and Independence Bay on the east coast, the polar bear is rare.

From the point of view of hunting the polar bear plays a great part in the Thule District; its skin is absolutely indispensable to the Polar Eskimo for trouser skins, for without this warm apparel it would be impossible for him to carry on hunting throughout the winter; also as rugs for sleeping platforms bear skins are better than anything else. As far as the remaining part of Greenland is concerned bear hunting is only of importance to three of the districts, *viz.* Angmagssalik, Julianehaab and Upernivik, where about 100, 32 and 17 bears respectively are killed annually. To this must be added the new settlement at Scoresby Sound, where 115 polar bears were killed during the first year of its existence.

Of *seals* there are 6 kinds in Greenland, *viz.* hooded seal, Greenland seal, ringed seal, harbour seal, bearded seal and walrus.

The *hooded seal* or *bladdernose* (*Cystophora cristata* Erxl.) is a North Atlantic species, with an uncommonly small distribution, seeing that, properly speaking, it only occurs in the seas round Greenland and hardly ever east of Spitzbergen and Iceland; towards the south it only very rarely roams as far as the British Isles. To a higher degree than the other

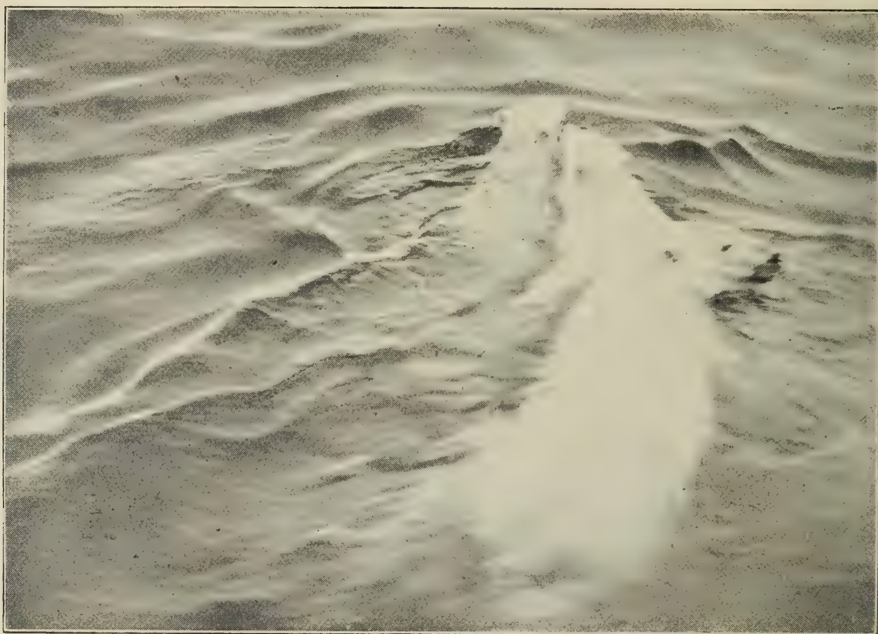

Fig. 6. Polar bears swimming. Photo by George P. Putnam, 1926. A she-bear with her cubs.

seals it is a marine animal. It lives chiefly far out at sea, at the great floes of drift ice in the Davis Strait and off the east coast, and only twice a year does it approach the land. In April—June herds of bladdernose haunt the southern west coast (Holsteinsborg—Julianehaab), and on this visit it is fat and well-fed. In June it disappears, but in July it returns once more in a lean state, and then only remains for three or four weeks. At the more northerly settlements on the west coast (Egedesminde—Upernivik) it appears late in summer and in rather small numbers; a few are caught as far north as at Cape York. To the southern east coast (Angmagssalik) the hooded seal generally comes from the north in the month of April, but it is few in number and disappears again in May; in July it comes back from the south, in greater numbers, and then remains until towards well into the autumn. Off northern East Greenland this species rarely appears on the coasts, and from the most northerly Greenland it is not known.

From an economic point of view the hooded seal is of great importance to the population in the Julianehaab and, partly, in the Frederikshaab District, where it is shot in great quantities among the floes of sea ice. In the northern districts it is only caught in any number worth mentioning at the outer islands, where kayaking skill is greatest.

The *Greenland seal* (*Phoca groenlandica* O. Fabricius) lives at certain seasons far from land, on the drift ice fields far outside the east coast

Fig. 7. Ringed seal's hole for ascending. After Frits Johansen.
North-east Greenland (Shannon Island). The ice is seven months old. April, 1908.

of Greenland in about lat. 72°—73° N. and far out in Davis Strait. At other times it appears off the coast, most frequently in flocks.

At the southern part of the west coast the Greenland seal appears in good condition in September, migrating from south to north between the islands; it gradually extends along the whole of the coast and into the fiords, but, by preference, keeping to the deep water. In October and November it is greatest in numbers; in December it decreases, and in February and March it disappears entirely, wandering away from the coast towards the west to the drift ice, where it brings forth its young. In more northerly West Greenland, particularly in the Egedesminde District, it remains until the ice forms, in mild years throughout the winter. In May or, off the more northerly part of the west coast, in June the herds return in a lean state, followed by their young and generally hunting caplin. Along

the coast they then remain until the latter part of July, when they disappear together with the caplin, and then again return in September.

To the southern part of the east coast (the Angmagssalik District) the Greenland seal also migrates twice yearly, in July and in September; in July both young and old appear from without, and they then occur singly, until the ice begins to be solid; in September they appear in shoals and then migrate towards the south. In Scoresby Sound the Greenland seal does not appear, neither off the coast nor farther north, at any rate only as an exception.

The Greenland seal does not make breathing holes in the ice; when the ice forms a large expanse, it repairs in herds to holes which are kept open by the current; if the water is entirely covered by solid ice, it keeps away.

The hunting of Greenland seal is very considerable; it is killed in great quantities, particularly off the southern part of the west coast. Its skin is used largely by the Greenlanders, as it is particularly fit for apparel, water-proof skins, dyed skins and skins for soles and kayaks.

The *ringed seal* (*Phoca foetida* O. Fabricius) is the most frequently occurring seal in Greenland, being distributed throughout the whole of the country; it lives even in northernmost Greenland, where no other seals occur.

The ringed seal mostly appears singly and never in large herds. All the year round it may live in about the same places and particularly in the very interiors of the fiords which cut deeply into the country and abut upon glaciers. It prefers fiords which remain ice-covered for a long period. It thrusts and scratches holes in the ice (fig. 7) in order to breathe, and it frequently creeps up on the ice to rest or to bask, or it keeps to holes and fissures caused by the tide or by the calving of icebergs. It brings forth its young on the ice, in the months February—April, by preference in a cave dug below the snow at the breathing hole which it has made for itself. The young and the middle-aged appear in winter at the mouths of fiords and off the coasts, but in the spring, in April—May, they return to the fiords.

The ringed seal is eagerly hunted, particularly at the northern settlements, where it must be regarded as the chief object of hunting. It is the seal which it is easiest to shoot, as its curiosity is apt to make it come within shooting range.

The *harbour seal* (*Phoca vitulina* L.) is a comparatively southerly species, which on the west coast hardly goes farther north than Upernivik and on the east coast as far as Angmagssalik, though a few are said to have been seen in Scoresby Sound. It lives scattered, is mostly encountered singly, sometimes several together, but not in large herds. It lives all the year round in the same regions, avoiding the ice wherever possible. It haunts the interiors of fiords as well as the outer coast, seeking isolated places far away from the dwellings of the Greenlanders. It frequently creeps up on

stones and skerries along the beach, sometimes also on ice, but where the ice lies solid, it is rarely to be seen. The skin of this seal is finer than that of the other seals, and therefore it is in particular request by the women for their gala attire. During later years the hunting of this seal has greatly decreased.

The *bearded seal* (*Erignathus barbatus* O. Fabricius) is few in number as compared with the other Greenland seals, and it mostly occurs scattered,

Fig. 8. A herd of walruses in low water at the sea shore. After Alwin Pedersen. Scoresby Sound, the summer 1924.

not in large herds. It keeps by preference to the ice, but it also occurs near the shore and in the interiors of bays.

It seems to be most numerous off the southern west coast, where it appears in spring with the pack ice, as well as on the northern part of the west coast, particularly round Nûgssuaq Peninsula. It still occurs in the Thule District, and Robeson Channel seems to be its northern boundary.

On the east coast it is of rather common occurrence all the year round at Angmagssalik; in Scoresby Sound it is not rare, and it is met with even farther north; however, it has not been observed north of lat. 77° N., nor have bones of it been found in the Eskimo ruins north of this latitude. Thus, it seems to be lacking on the stretch from Robeson Channel on the north coast to lat. 77° N. on the east coast.

Among the seals it is in size only inferior to the walrus. Its thick skin is of great importance to the Greenlanders, being cut into strips and used for

towing straps as well as for lashings on kayaks, umiaqs and sledges. Besides, the skin is used for covering umiaqs.

The total yearly number of proper seals caught in West Greenland (not including the Thule District) ranged in the years immediately preceding 1920 between 75,000 and 120,000, in 1920—24 between 70,000 and 90,000.

The *walrus* (*Trichechus rosmarus* L.) on the west coast is only a permanent resident between Sukkertoppen and Egedesminde—particularly at the mouth of North Strømfiord, where in the autumn it is in the habit of

Fig. 9. Narwhal (male). Photo by A. Bertelsen.
Ũmánaq (Nov. 9, 1913).

appearing in great numbers and creeps up on the islands round Taseralik—as well as in Upernivik District, Melville Bay and Smith Sound. In other places its occurrence is more sporadic. On the east coast it rarely appears at the southern part, but at Scoresby Sound it is in summer of comparatively frequent occurrence out at the coast and also farther north, and it has been observed as far north as at Amdrup Land (lat. 81° 10′ N.). North of this locality it has not been met with, nor in the part of the north coast which faces the Arctic Sea proper.

In the Thule District the walrus is of such great importance that it must be termed the chief animal of capture. It also plays a part in the newly established settlement on the east coast at Scoresby Sound. To the remaining part of Greenland it is of no great importance.

Sixteen species of *whales* are known in the seas round Greenland, *viz.* the cachalot, the bottlenose whale, the narwhal, the white whale, the caaing whale, the killer-whale, the common porpoise, the white-beaked dolphin, Eschricht's dolphin, Holböll's dolphin, the humpback whale, the blue whale, the common rorqual, the lesser fin whale, the Greenland whale and the southern right whale. Only three of these, *viz.* the narwhal, the

white whale and the Greenland whale have their homes about Greenland; the others are summer guests from the Atlantic.

The *cachalot* or *sperm whale* (*Physeter macrocephalus* L.) migrates in summer from the Atlantic into Davis Strait, but rarely comes close to the shore.

The *bottlenose whale* (*Hyperoodon rostratus* Pontoppidan) appears in summer, in small herds in Davis Strait and in the sea east of Greenland outside the drift ice, but it rarely approaches the shore.

Fig. 10. Head of narwhal (male.) Photo by A. Bertelsen.
It appears from the picture that the tusk passes through the upper lip. On the skin at the root of the tusk are seen parasitic crustaceans, called whale-lice *(Cyamus)*.

The *narwhal* (*Monodon monoceros* L.) is of common occurrence, though in comparatively few numbers, along the northern part of the west coast of Greenland, while south of Sukkertoppen it only appears rarely. In summer it is only present farthest north in Baffin Bay, in Smith Sound and as far as Hall Basin; not until the late autumn does it migrate towards the south; off Ũmánaq it does not appear until November, and already in March it may be encountered in Davis Strait, migrating towards the north. When the sea is suddenly covered with a wide expanse of ice, the narwhale resorts, in flocks, to some hole or other which it keeps open by constantly moving about in it; if the hole is very small, the animals make no attempt at leaving it, but remain there with the tusk projecting through the hole. If they find no natural holes, they may themselves break a hole or a row of

holes in the ice by means of the thick and firm cushion on the upper sides of their heads, in front of the blow hole. On such occasions *(savssat)* the Greenlanders, in a short time, are able to kill several hundred animals.

The narwhal is also of common occurrence along great parts of the east coast, and there it seems to occur farther towards the south in summer than on the west coast. At Angmagssalik it is rather common, as a rule appearing in the months May to August. Also in the region north of Angmagssalik and at Scoresby Sound it is rather common in summer, and it has been observed still farther north, up to about lat. 75° N. Farther north live specimens have not been encountered, but remains of narwhals have been found in the ruins of the former Eskimo habitations as far north as in lat. 80° 24′ N. North of this no trace of it has been found, nor along the part of the north coast facing the Arctic Sea proper.

The Greenlanders kill several narwhals yearly, both on the west and on the east coast.

The *white whale* (*Delphinapterus leucas* Pallas) is the most common whale along the west coast of Greenland, except at the southernmost part, where it only appears sporadically and in small numbers. It is very migratory; in summer it lives as far towards the north as ice conditions permit, in the autumn it migrates towards the south. In Baffin Bay and Smith Sound it appears in summer, in Disko Bay it is common in the months October to November, and only in mild winters is it to be met with all the winter through. At Godthaab it appears at the beginning of December, and its migrations, as a rule, do not extend farther than somewhat south of Fiskenæs. Throughout the winter it keeps along the west coast round the Arctic circle, and in April—May it returns, little by little, towards the north, so that when holes appear in the ice, in May and June, it is again numerous in Disko Bay, and in July it disappears entirely from there. During its migrations it frequently follows the coast, goes in among the islands and into the fiords. It then generally appears in herds, which during the migrations count as many as several hundreds or perhaps about a thousand.

When the winter ice lies solid and without holes over wide expanses, it is not to be met with. But in the more northerly parts of Greenland it frequently happens, when a severe cold suddenly sets in with calm weather, that a herd of white whale are cut off from the open water by a broad belt of ice, in exactly the same manner as was described in the case of the narwhal. In their distress they then try to find a spot or a crack with open water, and when the frost continues they do all they can to keep the hole open; such a herd is, in Greenlandic, called *savsat* (according to M. P. Porsild to whom we are indebted for the description of this event). If the opening is small in extent, the whales sometimes lie quite close to one another. At other times they only come up to the hole in order to breathe,

and then they generally have several holes in a long row over a distance of some kilometres, where they pass backwards and forwards.

From the east coast only few data are at hand regarding the white whale. At Angmagssalik it is occasionally seen and caught in July and August. Further, on a single occasion, it was observed farthest out at Scoresby Sound and at the mouth of Franz Joseph Fiord. On the other hand, it is known as being of common occurrence outside the ice-belt of the east coast in the region round Spitzbergen.

On the west coast of Greenland the white whale is sometimes hunted

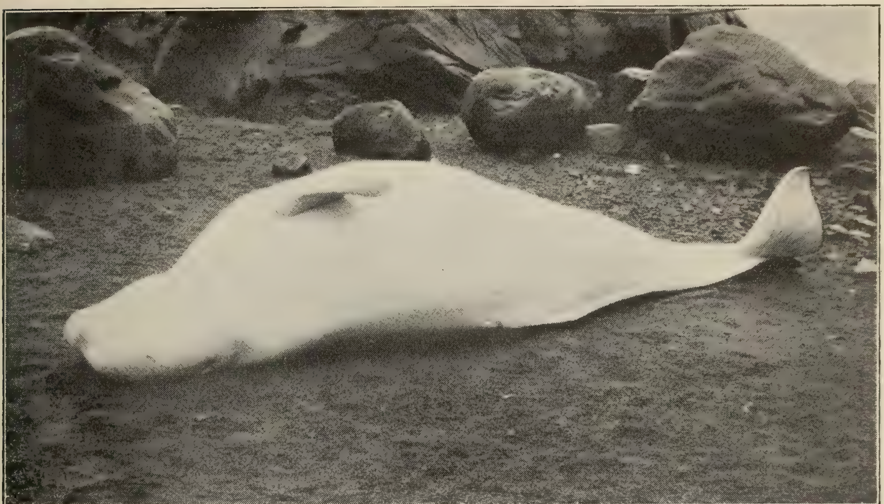

Fig. 11. White whale. Photo by A. Bertelsen.
Ũmánaq (Sept. 29. 1913).

from kayaks with harpoons or rifles, but mostly by means of nets. A special form of hunting is carried on at the above-mentioned *savssat*, where it is possible to kill several hundred white whales in the course of a few days. In some places the hunt has improved greatly during later years, as by means of motor boats, the noise of which greatly frightens them, the white whales are driven in herds into closed narrowings, from which escape is impossible; in that manner the number of white whales yearly killed at a settlement may amount to several hundred or even more than a thousand a year. Besides the meat and blubber, the skin is also valuable, as it can be made into leather.

The skin of this as well as other species of whales is called *mátaq* and is considered a special delicacy, being eaten raw as well as boiled and fried. It is an excellent remedy against scurvy.

The *caaing whale* (*Globiceps melas* Traill) sometimes appears in herds off the south-west coast of Greenland, as, for instance, in 1926, when about the middle of September some two hundred were killed at Sukkertoppen.

The *killer-whale* or *grampus* (*Orca gladiator* Bonnaterre), which generally appears in small herds, is of rather common occurrence along the shores of the sea west of Greenland from Frederikshaab as far as Upernivik; it is also known at Cape York. On the east coast it has been met with a few times at Angmagssalik and once in the outer part of Scoresby Sound.

The *common porpoise* (*Phocæna communis* Cuv.) is a common summer guest on the west coast of Greenland, from Cape Farewell to Upernivik; it is in the habit of appearing at the end of April, and disappears in November. It occurs in herds out among the islands as well as in the interiors of the fiords. On the east coast it is encountered at intervals of several years at Angmagssalik, when there is very little ice.

The porpoise is hunted like seals from kayaks or killed by rifles, the number of animals killed amounting to about 300—600 annually.

The *white-beaked dolphin* (*Lagenorhynchus albirostris* Gray) has only been met with a few times in Davis Strait on the coast of Greenland.

Eschricht's dolphin (*Lagenorhynchus acutus* Gray) has only been observed a few times in southern West Greenland; once a small herd appeared (September, 1858) off Kangeq, at the mouth of Godthaab Fiord.

Holböll's dolphin (*Prodelphinus euphrosyne* Gray) has only been found once along the west coast of Greenland.

The *humpback whale* (*Megaptera boops* O. Fabricius) is common along the west coast of Greenland, at any rate along the stretch from Frederikshaab to Disko; for the most part it occurs singly or in small flocks. It is a summer guest, appearing at the end of April and then again disappearing in November. On the east coast it is encountered, at long intervals, at Angmagssalik, when the pack ice has passed away.

At Frederikshaab the Greenlanders, from of old, have a special knack of killing this whale. In boats propelled by paddles they cautiously approach it while asleep, and three lances are thrust simultaneously into the region of its heart; then, the wounded whale is pursued by the boats until it is dead, and after the harpoon has been made fast to it, it is towed to the shore. This form of hunting has now entirely disappeared at Frederikshaab, nor has it been possible to maintain it in other places where it has been attempted.

The *blue whale* (*Balænoptera gigas* Reinhardt) and the *common rorqual or finner* (*Balænoptera musculus* Companyo) are, as far as is known, both of them common summer guests in the seas round Greenland. They appear in Davis Strait in the spring, migrating towards the north past the southern part of the west coast of Greenland into the Disko region and Baffin Bay, where they are encountered in summer; in the autumn they again appear off South Greenland.

The *lesser fin whale* (*Balænoptera rostrata* O. Fabricius) is of frequent occurrence, mostly in pairs or singly, along the west coast of Greenland, at least as far as Upernivik; it is said to occur most numerously towards the

south. It is a summer guest, being in the habit of arriving at Godthaab in April and disappearing from there in November and December. It occurs both out among the skerries and in the interiors of fiords. On the east coast it is as a rule seen at Angmagssalik, when the ice has passed away.

The *Greenland* or *arctic right whale* (*Balæna mysticetus* L.) has, according to H. Winge, been of common occurrence in the seas west and east of Greenland; but after having been extensively hunted by man for about three hundred years, it has, in the course of the 19th century, become quite rare east of Greenland; also, from the west coast of Greenland, where it has been subject to persecution for about two hundreds years, it has practically disappeared; along the west coast of Davis Strait and towards the north in Baffin Bay, where it was hardly hunted until the nineteenth century, the last remains of this strange creature are still to be found.

When it was still thriving, it occurred along the west coast of Greenland on the stretch from Smith Sound to Sukkertoppen; farther south it only appeared as an occasional straggler. As everywhere else it proved greatly dependent upon the ice, following by preference the margins of the large ice fields. In the warmest season, late in summer, in the months of July and August, it lived high up in Baffin Bay and in the sounds between the islands of arctic North America. In the autumn it migrated from there towards the south and east, one of its routes being along part of the west coast of Greenland; at Upernivik it was in the habit of appearing in October, at Godhavn in December and also at Sukkertoppen. To Upernivik it chiefly came from the north, to Godhavn and the region farther south in all probability partly from the west, perhaps only because on its way towards the south it deflected to the west of Disko, perhaps because its route of migration was partly from the west coast of Baffin Bay. From the more northerly part of the west coast, such as the Upernivik region, it fled during the severest winter cold, *viz.* from December, but it returned and remained from April to July. At Godhavn and farther towards the south it generally remained throughout the winter; from Sukkertoppen it then most frequently migrated in March, from Godhavn in June.

Off the east coast of Greenland it occurred in former times along the distance from about lat. 80° or farther north to about 65° or farther south. In the early summer it mostly haunted the sea between Spitzbergen and Greenland; in the months of June and July, when the belt of ice along the east coast of Greenland loosened and in part broke up, it approached the coast; then it partly migrated towards the north coast of Greenland, and partly it was encountered towards the south, as off Liverpool Coast. In the course of the autumn it seemed to roam southwards along the coast near the shore; when the floes of the drift ice off the shore began to freeze together, it migrated towards the margin of the ice belt and advanced far, both in a northerly and in a southerly direction. Throughout the winter

it probably frequented the ice margin off the more southerly part of the east coast, and in the early spring it again migrated towards the north, along the ice margin, so as to be able to be at Spitzbergen already in April.

It lives for the most part in smaller herds, by preference where the sea is covered by ice-fields, divided by channels of open water; it likes to stay below the ice, and is more rarely seen in the open sea. Ice which is not too thick, though of the thickness of a foot or more, it breaks by thrusting the upper part of its head against it, so as to make its way to the open air.

In the sea east of Greenland the Europeans began to hunt it in 1611; in Davis Strait, along the coast of Greenland, in 1719; in the "good" period the number yearly killed east of Greenland might amount to a couple of thousand, in Davis Strait to several hundred; now no Greenland whales are captured east of Greenland and only few or none west of that country; at the many former hunting grounds along the coasts of Greenland none have been harpooned since 1872.

The *southern right whale* (*Balæna australis* Desmoul.) has, on one occasion, been caught in Davis Strait on the coast of Greenland (Holsteinsborg, 1782).

During recent years the administration of Greenland has begun to carry on rational whaling off West Greenland, by means of a single whaling boat. In the year 1926 the number of whales killed amounted to : 9 cachalots, 2 blue whales, 24 common rorquals and 12 humpback whales. The animals killed are towed to the nearest dwelling place of some importance; here the flensing is undertaken by the Greenlanders, who in remuneration for their work receive the meat and the fat of the intestines, while widows and the needy get their share of the meat without any compensation. As the whale-boat is constantly changing its field of operation, a fairly large part of the coast is, in the course of the summer, provided with meat for winter consumption. The blubber is subjected to the same treatment as the seal blubber, being salted and, in Copenhagen, manufactured into oil.

Of *domestic animals* the Eskimos originally had only a single example, *viz.* the *dog*, which in North Greenland is still absolutely indispensable to the winter hunting. The farther north the greater the need of the assistance of the dog, and the greater the care required for its feeding. But south of the Holsteinsborg District sledging does not exist, as there is only navigable ice in the fiords, and as the snow has not drifted up and become firm, as in the regions farther north. Therefore, in South Greenland dogs are only kept as animals of luxury and for the sake of the skins. The number of sledge dogs has, in later years, fluctuated between 5500 and 6000.

Hunting and fishing are the chief occupations of the Greenlanders, but at some of the dwelling places of the Julianehaab District there is some cattle breeding, *viz. cows* and *sheep*.

In 1919 there were 60 head of horned cattle, all, with the exception of three, being the property of natives.

In order to encourage sheep raising, for which conditions are comparatively good in this district, the Government, in 1915, founded a fairly large sheep-raising station at the Julianehaab settlement. From this station the Greenlanders who desire to go in for this occupation are supplied with breeding animals, and the station also buys the products and ships them to Denmark. At the end of 1926 there were, besides the lambs, about 3000 mother sheep in the district. The station has at its disposal a few Icelandic horses, the only ones in Greenland.

Goats are kept throughout South Greenland, partly for the sake of the meat, partly and principally for the milk. In 1919 there were 186 goats in the Julianehaab District, of which 157 were the property of the Greenlanders.

Of other domestic animals attempts have been made at keeping *rabbits*; they can thrive, but up to the present the interest taken in this kind of breeding has not been very great.

Rats sometimes come to the country with vessels, but they generally die in winter.

II. BIRDS.

The immense area of Greenland and its considerable extent from south to north would seem to favour the development of a bird life comprising a great number of species. As far as the birds are concerned, access to the country offers no difficulty; thanks to their wings they can reach Greenland from all parts. But then the natural conditions of the country present themselves and place obstacles in their way. The conditions offered to the bird fauna are very poor; between the inland ice and the sea there is a narrow mountainous coast, without woods, here and there with sparse shrubs of willow, alder and juniper, in the region farthest south also birch; the fell-field vegetation is the prevailing one, interchanging with naked rocks; otherwise heath, mosspools, herbfields and, here and there grassfields; wood birds, which in many other countries with as northerly a position as Greenland constitute such an essential part of the bird life, are entirely lacking; of land birds there are only a few species which are accustomed to living on open land. By far the greater part of the bird life is associated with the shore; the resources of the sea are exploited by a swarm of birds of comparatively many species; at its surface sea gulls and fulmars seek their food; below the water auks, divers and cormorants hunt fish and crustaceans; from the bottom of the sea sea-ducks fetch forth shellfish, the sea-birds, in their turn, partly serving as food for sea eagles, falcons and ravens.

From Greenland 168 species of birds are known, according to Herluf

Winge and E. Lehn Schiøler whose descriptions of the birds of Greenland have been followed in the present treatise. Of those 51 breed in the country and so belong to the regular bird fauna of Greenland; 9 species can only with doubt be given as breeding (among others the *whooper swan* (*Cygnus musicus* Bechst.), which is exterminated as breeding); 107 species are stray guests, and one species (the *great auk*) is extinct.

Of the 51 species breeding in Greenland 28 are entirely or in part birds of passage, *i. e.* they leave Greenland in winter. The remainder, 23 species, constitute the permanent bird fauna of Greenland.

Among the stationary birds there are only 7 land birds, *viz.*

Ptarmigan (*Lagopus mutus* Mont.) breeds commonly on the west, north and east coasts.

Snowy owl (*Nyctea nivea* Thunb.), breeds rather commonly in the northern part of the country, probably most frequently on the east coasts.

Gyrfalcon (*Falco gyrfalco* L.), breeds rather commonly on the west and east coasts.

White-tailed eagle (*Haliaëtus albicilla* L.), breeds rather commonly on the west coast up to about lat. 70° N.

Raven (*Corvus corax* L.), breeds rather commonly on the west as well as on the east coast.

Mealy redpoll (*Acanthis linaria* L.), breeds rather commonly on the west coast and on the southern east coast.

Snow bunting (*Plectrophanes nivalis* L.), breeds commonly on the west coast as well as on the east coast.

However, these species are not entirely stationary. When the dark season closes in on the homes of those living farthest north, a movement towards the south sets in. On the west coast as well as on the east coast ptarmigan generally migrate towards the south, followed by the falcon. Also the snowy owl is driven somewhat farther south by snow, ice and darkness, while most ravens leave their northernmost haunts. The white-tailed eagle probably moves the shortest distance but then, as a breeding bird, it does not pass so far north; already in lat. 70° N. it is very rare, and on the east coast it does not occur. Snow buntings and mealy redpolls are said to migrate towards the interior of the country—the opposite of the species mentioned above, which migrate towards the coasts—and winter there; as to the snow bunting this chiefly applies to the old birds, whereas it is supposed that the young ones migrate towards the south across the sea.

Early in the year, when the light up in the north is beginning to return, but the winter is still severe, the ptarmigan appear in the northern breeding places; they are able to burrow down through the snow and thus to get at food. Falcon and snowy owls follow, the cold does not hurt them as long as they are able to find food. The eagles again resort to the inner reaches of the fiords, to the old breeding places at the salmon rivers.

Among the remaining 16 species of stationary birds there is a single wader, *viz.* the *purple sandpiper* (*Tringa maritima* Brünn.). The rest are swimmers, *viz*: *mallard* (*Anas boscas* L.), *long-tailed duck* (*Clangula hyemalis* L.), *harlequin duck* (*Cosmonetta histrionica* L.), *eider* (*Somateria mollissima* L.), *king-eider* (*Somateria spectabilis* L.), *Barrow's golden eye* (*Clangula islandica* Gmel.), *red-breasted merganser* (*Mergus serrator* L.), *cormorant* (*Phalacrocorax carbo* L.), *great black-backed gull* (*Larus marinus* L.), *glaucous gull* (*Larus glaucus* Brünn.), *ivory gull* (*Pagophila eburnea* Phipps), *Iceland gull* (*Larus leucopterus* Faber), *black guillemot* (*Uria grylle* L.), *Brünnich's guillemot* (*Uria lomvia* L.), *little auk* (*Mergulus alle* L.).

None of these species which are indigenous to Greenland leave their home, but in the strictest sense of the word stationary birds they are not, at any rate not those living farthest north. The mallard is more common in South Greenland in winter than in summer; long-tailed duck, harlequin duck and eider migrate towards the south in order to find open water, where they can get food; the more northerly red-breasted mergansers follow the example of the mallard and migrate to South Greenland; Barrow's golden-eye, the breeding area of which does not extend very far towards the north, now only migrates to the mouths of fiords. Also cormorants, black guillemots and little auks must make their way to the south, to open water. From the regions farthest north the ivory gulls pass down along the coasts of Greenland in order to fish at holes and lanes; white-winged and glaucous gulls leave their breeding and fishing places in the fiords, resorting to the extreme islands, to the ice margin and holes in the ice, and those from the farthest north come south; the great black-backed gull, which as a breeding bird does not reach very northerly regions, hardly beyond lat. 70° N., to a certain extent keeps the position, but when the darkness sets in it is obliged to leave.

The 28 species of birds which breed in Greenland, but leave it in the winter are the following: *white-fronted goose* (*Anser albifrons* Scop.); *pink-footed goose* (*Anser brachyrhynchus* Baill.); *snow-goose* (*Anser hyperboreus* Pall.); *brent goose* (*Branta bernicla* L.); *bernacle goose* (*Branta leucopsis* Bechst.); *red-throated diver* (*Colymbus septentrionalis* L.); *great northern diver* (*Colymbus glacialis* L.); *fulmar* (*Fulmarus glacialis* L.); *peregrine falcon* (*Falco peregrinus* Tunst.); *ringed plover* (*Aegialitis hiaticula* L.); *turnstone* (*Strepsilas interpres* L.); *red-necked phalarope* (*Phalaropus hyperboreus* L.); *gray phalarope* (*Phalaropus fulicarius* L.); *dunlin* (*Tringa alpina* L.); *knot* (*Tringa canutus* L.); *sanderling* (*Calidris arenaria* L.); *Sabine's gull* (*Xema Sabini* Sab.); *Kittiwake* (*Rissa tridactyla* L.); *arctic tern* (*Sterna macrura* Naum.); *Buffon's skua* (*Stercorarius longicaudus* Vieill.); *common skua* (*Stercorarius parasiticus* L.); *pomatorhine skua* (*Stercorarius pomatorinus* Temm.); *razor bill* (*Alca torda* L.); *puffin* (*Fratercula arctica* L.); *wheatear*

(*Saxicola oenanthe* L.); *water-pipit* (*Anthus spinoletta* L.); *Lapland bunting* (*Calcarius lapponicus* L.); *mealy redpoll* (*Acanthis linaria* L.).

Of the occasional guests among the birds which more or less rarely visit Greenland, 60 per cent. come from America, 36 per cent. from Europe-Asia, while 3½ per cent. may originate from both quarters.

Mention should be made of the following species of birds which are of importance to the Greenlanders:

The *eider* (*Somateria mollissima* L.) plays the greatest part among all the birds of Greenland; its flesh and eggs are eaten; the skin is used for apparel or sewn into eider rugs which, like the down, are purchased by the Greenland Trading Company. It breeds everywhere on the west coast, though rarely in its southern part, the more frequently the farther north it gets; as breeding places it chooses, by preference, low islands. Most eiders spend the winter in South Greenland, where every evening they pass towards the interiors of the fiords and every morning return to the shore. In April and May they again migrate towards the north in huge flocks.

The eider is pursued at all seasons, on its daily as well as on its yearly passage and during the breeding season. The yearly amount of eiders shot exceeds 150,000 birds, of which by far the greater part is in South Greenland, and about 60,000 eggs are collected, so that the yearly destruction of eiders amounts to more than 200,000. The consequences of this spoliation are obvious; the number of breeding birds decreases greatly. About 1885 South Greenland yielded at least 527 kg of down annually, in 1925 only about 78 kg, that is, the eiders at the present time only breed in quite a few places. At the beginning of the 19th century the annual amount of down purchased from the Greenlanders was, in the Egedesminde District, 1500—2000 kg, at the end of the century about 100 kg, about 1915 only some 30 kg. Not until we reach Upernivik and the regions farther north do we again encounter actual breeding places, but also here a noticeable decline is already now beginning to make itself felt.

With the object of procuring greatly needed protection for the eiders, a regulation was issued, in 1924, against killing or capturing eiders and their brood in South Greenland in the period between May 20th and August 31st; also, within the same period, it is forbidden to collect eggs or down from the nests.

King-eider (*Somateria spectabilis* L.) breeds along the northern part of the west coast of Greenland, from a little south of Disko Bay, but not until north of Upernivik does it become numerous. Only a few of these birds winter in the north; most of them migrate to South Greenland, where they stay during the winter and are caught in great quantities.

In Northeast-Greenland the king-eider is a rather common breeding-bird.

Brünnich's guillemot (*Uria lomvia* L.) is perhaps the most common bird

Fig. 12. Brünnich's Guillemot. After A. Bertelsen.

In their brooding place. Every projection in the steep rocky wall is occupied. The birds have finished brooding in the course of which they turn their breasts against the rocks. (August 10th, 1906).

in Greenland and of great importance to the population; the flesh is eaten, while the skins with the down attached to them are used for clothes, and loose feathers are collected for feather-beds or for sale. It mostly keeps out at sea and only rarely enters far into the fiords. It breeds in flocks, sometimes in huge swarms, on the ledges of steep rocks, in the company of other birds (fulmars, cormorants, seagulls, auks) or alone. Such bird cliffs (fig. 12) occur in great numbers, particularly in North Greenland; the greatest guillemot cliff is Qaersorssuaq at Upernivik, which is 3 miles in length, one of the highest in Greenland and covered with birds nests as far as the eye can reach. Brünnich's guillemot does not breed in southernmost Greenland, but is also to be found here, in great flocks, in summer. It should rather be described as a stationary bird, although from North Greenland it generally migrates towards the south in winter. At the bird cliffs great quantities are shot, and the people of the neighbourhood more or less live on it throughout the summer.

With severe cold or snow thickness Brünnich's guillemot comes ashore in great numbers and resorts to the fiords which are most free of ice, particularly in the Julianehaab and Godthaab Districts. Here it is caught with bird darts, not merely by the regular hunters, but by all who are able to paddle a kayak, from old men to boys of ten or twelve, or killed with small shot. In a few places the hunting is done by several kayaks surrounding a large flock of guillemots, driving them into a narrow bay and then gradually right up on land, where it is possible to catch them by hand because they cannot fly up from the land. When the fiords freeze over, the guillemots are shot at holes, and when the latter also freeze over, they can be caught by hand, as they cannot fly from the ice. The number of guillemot shot every year is estimated at about 100,000.

The *little auk* (*Mergulus alle* L.) commonly breeds on the northern part of the west coast, in winter migrating to South Greenland. It is killed in great numbers; and particularly to Cape York, where it builds in millions at all the cliffs, it plays the very greatest part, partly as a supplement to the winter fare, partly by supplying the many small skins for inner jackets.

The *black guillemot* (*Uria grylle* L.) occurs as a common breeding-bird along all the coasts of Greenland; however, it does not occur on the north coast, as in these localities there is no open water in summer. It is a stationary bird, in so far as it is not driven away by the ice. It is less valuable than Brünnich's guillemot and does not occur in such great numbers.

The many different species of *sea gulls* are shot at the cliffs or during their summer and autumn passage.

Of other sea birds which are occasionally hunted, may be mentioned: *puffin* (*Fratercula arctica* L.), *common skua* (*Stercorarius parasiticus* L.),

various species of *ducks* and *geese*, *mergansers*, *cormorants* and *divers*. Most appreciated by the Greenlanders is the *cormorant* (*Phalacrocorax carbo* L.), as the flesh, particularly of the young birds, is a favourite dish and the skin in great request, but owing to persecution it has, during later years, become rarer and rarer. It occurs along the west coast, chiefly breeding north of Godthaab and inhabiting steep rocky walls at the sea with its nest at the top; many cliffs along the shore derive their names from it.

Besides the profit yielded by the flesh of the birds, the Greenlanders collect great quantities of eggs, feathers and down. Of particular value is the eider down, but owing to the spoliation taking place the native export of this merchandise is now much smaller than in former times.

Of land birds which form objects of chase, only one species, the *ptarmigan* (*Lagopus mutus* Mont.), occurs. It is to be met with everywhere in Greenland, even on the north coast facing the Arctic Sea, on the islands and coast cliffs, as well as right up to the inland ice. It is mostly encountered on the coast cliffs from September to May. Its occurrence is very variable; one year ptarmigan may be very few in number; then again in the following year they may be very numerous, and once in a while, in the so-called "ptarmigan years," they may occur in such abundance as to be met with in huge flocks, even at inhabited places. When the latter is the case, it is thought to be due to the fact that the snow farther inland is covered by such a strong ice crust that the ptarmigan cannot get down to their food and, therefore, migrate to the coast.

Ptarmigan is not hunted by the real Greenland hunters, except occasionally; therefore, the hunt is almost exclusively carried on by half-grown boys and people who cannot go out in kayaks, as well as by Europeans. The Greenlanders themselves do not eat ptarmigan when other food is to be had; so all the birds killed are sold to the Danes, who frequently get so many that they are able to preserve them for consumption during the summer or for sale.

In South Greenland it is forbidden to shoot or catch ptarmigan in the period May 1st—August 15th, and it is not allowed to remove eggs from the nests.

Of tame birds *domestic fowls* are kept by the Danes everywhere in South Greenland and in North Greenland at the settlements of Disko Bay, as well as in the Ũmánaq District.

III. FISHES.

100 species of fishes are known from Greenland.

If first of all we consider the fauna of the deeper water, then the submarine ridges, which about the Arctic circle extend from Iceland to East Greenland and from West Greenland to Baffin Land, form the boundary

between two faunas. Denmark Strait, south of the Iceland-Greenland ridge, contains species of fishes which it has in common with the depths of the Atlantic, and which especially belong to the *Macruridae*; on the other hand, north of the ridge there are species which it has in common with the deep Greenland Sea, as *Lycodes frigidus* Coll., *Paraliparis bathybii* Coll. and *Rhodichtys regina* Coll. In Davis Strait, south of the ridge, there is also an Atlantic fish fauna, characterized by such fishes as *hag-fish* (*Myxine glutinosa* L.), *Fabricius' dog-fish* (*Centroscyllium Fabricii* Reinh.), several species of skates, and *Macrurids*, *pole-dab* (*Pleuronectes cynoglossus* L.), *Cottunculus Thomsonii* Gthr., etc.; north of the ridge we have, on the other hand, in deep water a fish like *Raja hyperborea* Coll., which occurs everywhere in the Greenland Sea Deep. Also in the coast waters a difference may be demonstrated, as far as the east coast is concerned; here Angmagssalik (about lat. 65° 35′ N.), which is situated on the south side of the ridge, forms the northern boundary of the occurrence of *caplin* (*Mallotus villosus* Müll.), the *Norway Haddock* (*Sebastes marinus* L.) and *torsk* (*Brosmius brosme* L.); neither are *cod* (*Gadus callarias* L.) and *halibut* (*Hippoglossus vulgaris* Flem.) met with farther north. On the west coast these fishes, on the other hand, extend much farther north, the caplin, for instance, to the middle of Vaigat (about lat. 70° N.), the Norway haddock to about lat. 71° N., cod and halibut sometimes as far as into Disko Bay, although as a rule they do not extend farther north than lat. 67°—68° N. As a fish which only occurs in the northern parts may be mentioned the *four-horned Cottus* (*Cottus quadricornis* L.); on the east coast it does not extend farther south than Turner Sound (lat. 69° 44′ N.), on the west coast only as far as Baffin Bay.

In the fresh waters of Greenland only 4 species of fishes occur, *viz. salmon* (*Salmo salar* L.), *eel* (*Anguilla rostrata* le Sueur), *charr* (*Salmo alpinus* L.) and *three-spined stickleback* (*Gasterosteus aculeatus* L.); the salmon, however, occurs rarely, in fact, only in a few rivers in the Holsteinsborg and Godthaab Districts, and the eel, which is the American, not the European species, very rarely in rivers and lakes in the Julianehaab District. These fishes also occur in salt water.

Of the fishes special mention is otherwise only to be made of those which are most important to the population.

The *cod* or *kabliau* (*Gadus callarias* L.) on the west coast only appears in any great number in the summer and autumn months, and is otherwise very variable in its occurrence. In certain years only few and scattered shoals appear, whereas in others the cod may appear in great shoals and over great parts of the coast, from the very south point of the country as far as lat. 66° 45′ N. During more recent years we know of two such periods. From 1908 to 1916 cod in any quantity worth mentioning only occurred in a few places, but since 1917 cod have appeared in great quantities, first in the Julianehaab District and in some years also in the Frederikshaab District,

since 1919 also in the Godthaab District and since 1922, further, in the Sukkertoppen District. During the very latest years cod have also, for a short period during the summer, appeared on the banks off the coast, mostly on Fylla Bank, where they did not occur in the years when cod were scarce. These great fluctuations in the number of cod are probably due to the fact that the cod spawn are in certain years abundant and in the course of a given number of years grow into large cod, whereas in other years the cod spawn are less abundant, with the result that after a corresponding number of years there will be few large cod. Besides being used in the country itself, the cod have of later years received an added importance to the native population, in that the Greenland Trading Company buy cod from the natives and prepare them for export as salt fish and stockfish. The cod bought from the Greenlanders in the period 1912—16 amounted to between 23,500 and 124,500 kg annually, in the period 1917—25 between 243,500 and 956,000 kg (in 1926: 2,055,000 kg).

The *halibut* (*Hippoglossus vulgaris* Flem.) occurs in the early summer in the deep and constantly "warm" (about 3° C. at the bottom) water off Great Hellefiske Bank. In the course of the summer a rise of temperature occurs above this bank, the comparatively shallow water of which, after being greatly cooled in winter, is gradually warmed by the atmosphere and the sun, and only then the halibut migrates across the bank towards the coast, particularly on the stretch between Agto and South Ström Fiord. In the autumn, when the coast water is cooled, the halibut must once more retreat to the depths of Davis Strait.

In former times the Greenlanders captured this large fish from kayaks and by means of hand lines, but after the Greenland Trading Company had begun to purchase halibut, the fishery has mostly been carried on from boats, partly motor boats, and with long lines. In 1926 the yield of the halibut fishery amounted to 270,000 kg (dressed fish), besides what the Greenlanders used for their own needs. The fish purchased from the natives were partly salted in barrels, partly preserved in tins.

The *Greenland halibut* (*Reinhardtius* (*Platysomatichthys*) *hippoglossoides* Walb.) is a deep-water fish (about 300—1000 m), which occurs in greater quantities, partly in Davis Strait, partly in a few places at the west coast of Greenland, *viz.* in Ũmánaq Fiord, at Qeqertaq in the Ritenbenk District, and particularly at the iceberg bank of Jacobshavn, as well as in some fiords in the Julianehaab District. Out in the depths of Davis Strait its ova and quite small young are to be found bathypelagically, whereas the older young come up close to the surface, where they are subsequently transformed and again return to the bottom. This flat-fish, which attains a weight ranging between 5 to 10 kg, has considerable value as a commodity of export, its flesh being extremely fat and suitable for being smoked like salmon. The fillet is cut from the back bone and salted into barrels, which are sent to

Copenhagen, where the fish is smoked and sold. Within the period 1910—25 exports have fluctuated between 700 and 2750 barrels yearly. Large quantities, especially of underweight fish are used by the native population, in North Greenland also for the feeding of the dogs, which must be kept in good condition, as they play such a great part in the winter hunting of the Greenlanders.

On the east coast the Greenland halibut occurs at Angmagssalik.

The *Greenland shark* (*Somniosus microcephalus* Schneider) is extremely widely distributed in West Greenland from the south point right up to Wolstenholme Fiord, in fiords, at the sea shore and far out in Davis Strait. This shark is generally 2.5 to 4 m in length and may be up to 5.5 m. In winter it is caught through holes in the firm ice, in summer from small wooden boats and kayaks. The most important produce of the shark is the oil which is extracted from the liver; in Greenland it is used as lamp oil, but the greater part of it is exported. In North Greenland where the dog plays such a great part in drawing sledges, the shark fishery has the added importance of supplying food for the dogs; when fresh the shark's meat contains some sort of poison, but when dried it yields excellent dog food. In later years the annual number of sharks caught amounts to about 35,000, yielding about 7000 barrels of liver, in one or two years even amounting to 50,000. On the east coast the Greenland shark is known from Scoresby Sound, and it is very common at Angmagssalik where the shark fishery is of great importance to the inhabitants.

The *charr* (*Salmo alpinus* L.) is of very common occurrence on the west coast, in fiords, rivers and lakes, from the southernmost parts right up into the Thule District.

There are charrs which inhabit the sea and from there ascend the rivers in order to spawn; they become rather large (40 to 75 cm in length and 1 to 6 kg in weight), but there are also forms which exclusively live in fresh water, even in small lakes and rivulets, where they only attain a small size (16 cm). The numerous rivers are visited by the Greenlanders when the salmon is ascending in order to spawn (July and August), and salmon fishing is one of their summer pastimes. Part of the catch is eaten on the spot, boiled, or sold fresh or smoked for the Danes, while part of it is dried for winter provisions. There are only few rivers where salmon fishing is undertaken with a view to export, for only a very few can supply an amount of fish sufficiently large to pay expenses. The fact is that the ice-free outer land of Greenland is narrow and drained through an infinitude of rivulets, each of them being the spawning ground of a moderate number of salmon—rivers in the strictest sense of the word do not exist. In 1914, at a fiord with several particularly good salmon rivers, an experimental station was established for the preserving of salmon, but after three summers this industry was given up, as the number of salmon was too small to begin with

and their number, furthermore, decreased alarmingly. The exploiting of the salmon rivers is therefore still done in the former manner; barrels and salt are transported out to the rivers; here the cleaning and the first salting of the salmon take place; then the barrels are shipped to the settlements, resalted and sent home in the course of the year. The quantity of salted salmon exported varies considerably, fluctuating between about 100 and 550 barrels annually. The greater part comes from rivers in the Holsteins-

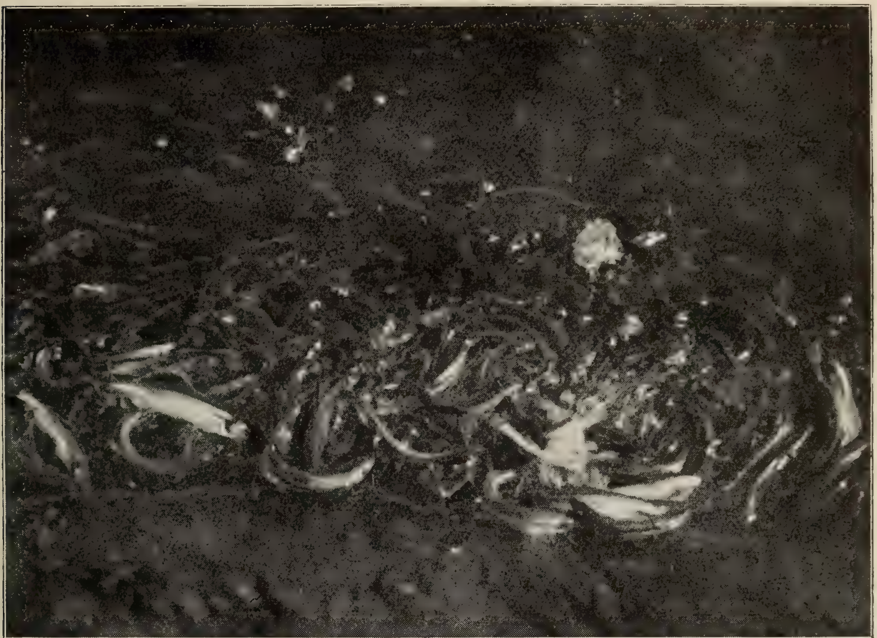

Fig. 13. Caplin in shoals along the coast at spawning time. Photo by H. Deichmann. Holsteinsborg, June, 1908.

borg and Sukkertoppen Districts; the outer land in this place being broadest and the rivers therefore fairly large. The salted salmon is not fat enough for smoking and so must be used in some other way. The market value is further diminished in that not all salmon have red flesh; many of them are "white" salmon, as they are called, otherwise every possible shade between "red" and "white" salmon are to be met with.

On the east coast *Salmo alpinus* is known from Danmark Harbour, Sabine Island and Scoresby Sound, as well as from Angmagssalik, where it is common throughout the district and runs up the rivers from the end of July till the latter half of September.

The *caplin* (*Mallotus villosus* Müll.), by the Greenlanders called *angmagssaq* pl. *angmagssat*, a small herring-like salmon, is practically lacking in the Upernivik and Ũmánaq Districts, but from Disko Fiord and the middle of Vaigat, right down to the southern point of the country, it goes regularly

inshore every year in immense shoals in order to spawn (fig. 13), thus giving rise to a fishing industry which, for Greenland, is very considerable. During the months May, June or July it crowds to the shore for a period of four weeks. However, it does not occur everywhere; for instance, it does not visit the rocky islands of the "Skærgaard", the good caplin grounds being situated in the fiords, where the beach is shallow and sandy or, at any rate, level. Therefore, people must go to the caplin grounds, every dwelling place as a rule having a special spot to which the inhabitants resort. Women and children are taken along, for all must assist in this fishery, which simply consists in scooping up, at certain hours, the caplin, closely packed along the shore, by means of pails and catchers and spreading them on the rocks to dry. The caplin is of the very greatest importance to the population of Greenland; large quantities are boiled and eaten on the spot, while the fish dried on the rocks are gathered in bags or strung, to be kept as reserve provisions for the winter season. About the middle of the 19th century Rink estimated the yearly production, in South Greenland only, at about 750,000 kg. At the northerly settlements, where the dogs play a great part, both for communication purposes and for the winter hunting of the Greenlanders dried caplin are, furthermore, an important item of their food.

The *fiord cod* or *ûvaq* (*Gadus ogac* Rich.) frequently occurs in West Greenland, from the most southerly up to the southern part of the Upernivik District, indeed, even farther north, right up to Tasiussaq (lat. 73½° N.). It keeps to coasts and fiords, from the shore down to more than 400 m. It generally weighs ½ to 4 kg, but may attain a weight of some 7 kg. The fiord cod is of great importance to the Greenlanders, as it is easy to catch and is generally always available, even when other provisions are scarce. An experiment has been made at preparing larger consignments of this cod fish as stockfish and salted fish, but it has not proved possible to find a market for it, as it is generally too small and too lean.

The *Norway haddock* (*Sebastes marinus* L.) occurs at West Greenland, from the southernmost part as far as about lat. 71° N., and from the interiors of the fiords, far out into Davis Strait; still, it requires at least 60 m of water, and the great Norway haddock generally inhabits depths of about 160 to 400 m. It is, however, not equally frequent everywhere, being as a rule looked for on certain banks; most frequently it is met with in the Frederikshaab District. It may attain a weight of 7 kg, but is generally considerably smaller. At various places the Norway haddock is of importance to the Greenlanders; the flesh is savoury, and oil can be extracted from the fat, which in an emergency can be used for the lamps. On the east coast, where its northern boundary is at about lat. 66° N., it is common at Angmagssalik.

The *sea scorpion* (*Cottus scorpius* L.) is distributed along the whole of the west coast, right up to the Thule District. It occurs almost everywhere

in great numbers, and as it is to be had all the year round, it is of great importance to the population as food in times of scarcity. It is mostly caught by boys, who take it with jigs from kayaks and through holes in the ice. On the east coast it is common in the Angmagssalik District and at Scoresby Sound; farther north it has been identified at Sabine Island, in Clavering Sound and at Danmark Harbour (lat. 77° N.).

Two other common *cottoids, viz. Cottus scorpioides* Fabricius and *Gymnacanthus tricuspis* Reinhardt, are caught and used in the same manner as *Cottus scorpius.*

The *lump sucker* (*Cyclopterus lumpus* L.) is common on the southern west coast and has its northern boundary in the Ũmánaq District. It goes inshore in April and May in order to spawn. The meat is eaten boiled and dried, and the spawn, which is large and greenish, is gathered and regarded as a great delicacy. On the east coast it is not uncommon at Angmagssalik.

The *long rough dab* (*Hippoglossoides* (*Drepanopsetta*) *platessoides* O. Fabricius) is of common occurrence at West Greenland, from the most southerly part, at least as far as South Upernivik (lat. 72° 10′ N.), alike in the fiords, at the shores of the sea, on the banks and far out in Davis Strait, as well as throughout Disko Bay, from the beach out to above a depth of more than 700 m. This flounder, which attains a weight of 1½ kg, in certain places has some importance as food. On the east coast it has been caught at Angmagssalik and as far up as lat. 72° 25′ N.

The *sea cat* (*Anarrhichas*) occurs in three different species, of which the *common sea cat* (*A. lupus* L.) and the *spotted sea cat* (*A. minor* Olafsen) form a highly appreciated dish.

The *polar cod* (*Gadus saida* Lep.) occurs throughout the west coast, but is most frequent in the northern districts, where in spite of its small size (about 20—38 cm) it is of some importance as food for the population, because it arrives in shoals during the dark winter season when other provisions are scarce. On the north coast of Greenland it was caught on the coast of Gunnar Anderssons Valley by the Second Thule Expedition (1917). On the east coast it is of common occurrence at Angmagssalik and Scoresby Sound, and it has been identified as far north as at Sabine Island.

IV. INVERTEBRATES.

Of *insects* there are 437 species, distributed over the various orders in the following manner: 41 *beetles* (*Coleoptera*), 66 *membrane-winged* (*Hymenoptera*), 188 *two-winged* (*Diptera*), 6 *fleas* (*Siphonaptera*), 46 *butterflies* and *moths* (*Lepidoptera*), 2 *lace wings* (*Planipennia*), 5 *caddis flies* (*Trichoptera*), 1 *may-fly* (*Ephemerida*), 2 *book lice* (*Copeognatha*), 1 *earwig* (*Dermoptera*),

1 *cockroach* (*Blattidæ*), 1 *thrips* (*Thysanoptera*), 43 *biting lice* (*Mallophaga*), 7 *sucking lice* (*Anoplura*), 13 *bugs* (*Hemiptera Heteroptera*) and 14 *springtails* (*Collembola*).

As it appears, the two-winged are the order which is most richly represented in Greenland, several of these by a great number of individuals. Two families are particularly noticeable, *viz.* the mosquito and the buffalo gnat. The *Greenland mosquito* (*Culex nigripes* Zett.) occurs along the west coast in enormous swarms and is a dreadful torment. The larvæ and the puppæ are common in all water holes throughout the summer, and the mosquito itself appears from the middle of June till some time in August. In the Christianshaab District the mosquito pest, in all probability, reaches its culmi-

Fig. 14. The Greenland mosquito *(Culex nigripes)*, female, magnified $3\,^1/_2$ times. After Will. Lundbeck.

Fig. 15. Buffalo gnat *(Simulium vittatum)*, female, magnified $4\,^1/_2$ times. After Will. Lundbeck.

nation, whereas at Upernivik it is said to be greatly diminished. The Greenland mosquito also occurs on the east coast. Of *buffalo gnats* (*Simulium*) two species are encountered along the west coast, and the one in particular (*S. vittatum* Zett.), which occurs in huge swarms from the middle or the end of July till the end of August, is at least as great a pest to human beings as the mosquito. Of midges there are otherwise many species of the families *Chironomus* and *Tanypus*. Also of flies proper there are a great number, for instance, flower-flies, a couple of *Empidæ*, blow-flies *et al.* The common house-fly does not occur, whereas the *lesser house-fly* (*Fannia canicularis* L.) is not infrequent.

The membrane-winged are, with the exception of some *Tenthredinidæ* and a couple of *humble-bees*, all *ichneumons*.

Among the *Lepidoptera* there are only 4 butterflies and of those only two are common, *viz.* a *fritillary* (*Argynnis chariclea* Schneid.) and a *yellow* (*Colias hecla* Lefeb.).

The beetles are represented by species of *carabids*, *water beetles*, *rove beetles*, *weevils*, a couple of *longicorns* which undoubtedly are imported, and

one *lady-bird.* Most beetles are of the rapacious class, whereas the large families of lamellicorn beetles and leaf beetles are not at all represented.

Five species of insects occur living parasitically on man. The *human flea* (*Pulex irritans* L.) has in recent years been found on the west coast, so that the Greenlanders, who formerly knew nothing of fleas, are now beginning to be infested with these insects.

The *head-lice* and *body-lice* (*Pediculus capitis* Deg. & *P. corporis* Deg.) are common among the Greenlanders throughout the west coast as far as Cape York, and also among the Greenlanders inhabiting the east coast.

The *crab-louse* (*Pthirius pubis* L.) still only seems to occur sporadically and is, beyond a doubt, imported. The Greenlanders lack both pudical and axillary hair, so that in former times this parasite could not subsist on them; nowadays it is also chiefly the more hairy mixed Greenlanders who are infested with them.

The *bed-bug* (*Cimex lectularius* L.) has been found in native huts at the Holsteinsborg Settlement.

Arachnids (*Arachnida*) number 124 species, of which 1 *harvestman* (*Opiliones*), 1 *false scorpion* (*Chernetidæ*), 46 *spiders* (*Aranea*), 66 *mites* (*Acarida*) and 10 *bear-animalcules* (*Tardigrada*). Of spiders the most frequently occurring are some species of hunting spiders; of spinning spiders there is, *inter alia*, a cross-spider which spins its wheel-like web in willow-copses. A number of mites (*Ptytoptidæ*) form galls on plants. The *itch mite* (*Sarcoptes scabiei* D. G.) has been met with throughout the west coast, now sporadically, now almost on every individual in a dwelling-place.

According to Henriksen and Lundbeck, who in 1917 published a revised, complete list of the land arthropods of Greenland, the bulk of insects and arachnids are purely European forms, some with a wide distribution in a north-south direction, but most of them purely arctic animals. Further, a small number of arctic circumpolar species are distributed along the northern coasts of all three parts of the world. Finally, 79 species of insects and 30 arachnids are endemic, and only very few forms (12 Diptera, 1 flea, 5 Lepidoptera and 4 arachnids) belong to purely American species, and of these only a single one (the flea) to a purely American family. "Therefore, in spite of its geographical position, Greenland on the strength of its (land arthropod) fauna must be said to belong to Europe."

The crustaceans in number surpass the two former classes of arthropods, amounting in all to some 742 species. Of *decapods* there are 44 species, but of *amphipods* 232 species, of *isopods* 94 and of *tanaids* 55. Among the *small crustaceans* (*Entomostraca*) the *copepods* predominate, free-living or parasitical and are represented by about 142 species.

Among the crustaceans of the sea there are a number of *prawns, inter alia, Sclerocrangon boreas* Phipps, which lives in low water and attains a length of about 14 cm; but the flesh being dry, it is not eaten, whereas the

red deep-sea prawn (*Pandalus borealis* Kr.), which is blood-red when alive, is extremely palatable. Among the crabs may be mentioned the large *Greenland crab* (*Chionoecetes opilio* O. Fabr.), about 80 cm between the extreme points of the longest claws, whose flesh is also very palatable. Of isopods may be mentioned the *Æga* species living parasitically on fish, and the *whale lice* (*Cyamus*), which subsist by the thousands on whales, devouring their thick epidermis; on the narwhal they are lodged in the skin fold round the exposed part of the tusk of the male (see fig. 10). On the rocky coasts the *sessile barnacles* occur in great numbers on the water line, together with *periwinkles* (*Litorina*); other *cirripeds* (*Coronula, Conchoderma*) subsist on the skin of whales ("whale cups)." Of *copepods* numerous species subsist parasitically on fishes (*Lernæa, Lernæopoda, Chondracanthus,* etc), among others the *Lernæopoda elongata* Grant, several centimetres in length, which frequently attaches itself to the eye of the Greenland shark. Many species, both *amfipods, Euphausiacea, Mysidacea* and *copepods* live pelagically and may occur in innumerable quantities.

In fresh water there are only some 60 species of crustaceans; most of them are small forms, such as *Copepoda, daphnids* (*Cladocera*) and *Ostracoda*; larger (by a couple of centimetres) is *Lepidurus arcticus* Pall. and *Branchinecta paludosa* O. Fr. Müll.

Of arthropods there are, further, 34 species of the so-called *sea-spiders* (*Pycnogonida*).

Of molluscs (*Mollusca*) there are 247 species, *viz.* 5 *Placophora,* 146 *Gastropoda,* 5 *tooth-shells* (*Scaphopoda*), 79 *bivalves* (*Lamellibranchiata*) and 12 *cephalopods.* Particularly well known is the large (10 cm) *scallop* (*Pecten islandicus* O. Fr. Müll.) which the Danes gather in certain localities of the west coast (Holsteinsborg, Egedesminde), especially when they want to treat guests to a real Greenlandic delicacy, its adductor muscle in particular having a very fine taste. Numerous is the *common mussel* (*Mytilus edulis* L.); it may be gathered nearly everywhere at low water and is to the Greenlanders a kind of emergency fare.

On the east coast the northern limit of the common mussel is already at lat. 66° 30 'N., on the west coast it extends much farther north, at least as far as Ũmánaq (in about lat. 70° 40′ N.). In a fossil state the common mussel, on the other hand, has been found in raised strata along the east coast, as high up as in about lat. 73° N. A parallel of this is met with on the west coast, where in raised, post-glacial strata at lat. 68° 37′ N. shells are found of *Zirphæa crispata* L. and *Anomia squamula* L., two bivalves which now no longer occur in Greenland, and the present northern limit of which is farther south, *viz.* at Gulf St. Lawrence and southern Labrador, respectively. These and other similar finds show that the sea water along the coasts of Greenland, during a period succeeding the ice age, has been considerably warmer than it is at the present time. On the other hand,

during a still earlier period of the Quaternary age, the sea climate of Greenland has been severer than at the present time, as is shown by the occurrence of the high-arctic bivalve *Yoldia* (*Portlandia*) *arctica* Gray as a fossil in several places within the Disko Bay area, whereas now it does not occur farther south than in Melville Bay and Murchison Sound, *viz.* in lat. 75½—77½° N.[1] In the Quaternary periods there has thus, along the more southerly part of West Greenland, been a high-arctic sea of ice, at the bottom of which lived *Yoldia arctica* and other animals, which could subsist in the same low temperature. Later on the temperature rises, *Yoldia arctica* is forced to migrate towards the north, and during the culmination of the warm period the southern forms *Anomia* and *Zirphæa* immigrate. This culmination of temperature is gradually succeeded by the present conditions, where the "chilly" forms, *Anomia* and *Zirphæa*, have passed far towards the south, whereas the "cold-loving" *Yoldia arctica* keeps far towards the north.

Pelagically there live in immense swarms 3 species of winged-snails (*Pteropoda*), the two testaceous (*Limacina helicina* Phipps and *L. balea* Møll.) and one naked (*Clione limacina* Phipps).

Of molluscs there live in fresh water 1 bivalve (*Pisidium*) and 5 gastropods of the families *Limnæa* and *Planorbis*. To the land fauna belong 5 testaceous snails of the families *Succinea*, *Pupa*, *Conulus* and *Vitrina*.

Of *sea-squirts* (*Tunicata*) there are 56 species, *viz.* 4 *Appendicularia*, 47 *ascidians* (*Ascidiacea*) as well as 5 *salps* (*Thaliacea*).

The *arrow-worms* (*Chætognatha*) are represented by 5 species, *moss-animals* (*Bryozoa*) by 146 (among which 2 are in fresh water) as well as *lamp-shells* (*Brachiopoda*) by 6 species.

Of annelids (*Annelida*) there are 225 species, *viz.* 200 *bristle-footed worms* (*Chætopoda*), 16 *leaches* (*Hirudinea*) and 9 *Gephyrea*. In South Greenland there are, further, two species of *earthworms* (*Lumbricus*) and in fresh water a number of other *Oligochæta*.

Of lower worms (*Scolecida*) there are 246 species, *viz.* 38 *Turbellaria*[2], 20 *flukes* (*Trematoda*), 39 *tapeworms* (*Cestoda*), 88 *wheel-animalcules* (*Rotatoria*), 20 *thread-worms* (*Nematoda*), 10 *thorn-headed worms* (*Acanthocephala*), 6 *Entoprocta* and 25 *ribbon worms* (*Nemertini*). Of tape worms two species have been found as human parasites, *viz. Dibothriocephalus latus* L. once in a Greenland woman, and *D. cordatus* Leuck., three times in Greenland women, the latter species in Greenland otherwise occurring with dogs, walrus and Greenland seal. Of round worms the *maw-worm* (*Oxyuris vermicularis* L.)

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[1] On the east cost, this bivalve, as was to be expected, (cf. *Cottus quadricornis*) goes considerably farther south, *viz.* to lat 69½° N.

[2] From an expedition undertaken to Greenland in 1926 Dr. Reisinger and Dr. Steinböck succeeded in identifying 176 species of *Turbellaria* (of which at least 115 are new to science) 42 in fresh water and 134 in the sea. These authors arrive at the result that at least 35 of the 42 fresh water species derive from America.

is of very common occurrence with the Greenlanders, adults and children alike, throughout the west coast. The human *Ascaris* (*Ascaris lumbricoides* L.) is less common.

Of echinoderms 90 species occur, *viz.* 16 *sea-cucumbers* (*Holothuroidea*), 32 *star-fishes* (*Asteroidea*), 28 *brittle-stars* (*Ophiuroidea*), 7 *sea-urchins* (*Echinoidea*) as well as 7 *sea-lilies* (*Crinoidea*). Extremely common is the sea-urchin *Strongylocentrotus dröbachiensis* O. Fr. Müll.; in many places, with shallow, transparent water the bottom, on stretches of several kilometres, is seen to be entirely covered by this animal, as also the foot of the rocks below the water.

Of *Coelenterata* 352 species are known, *viz.* 155 *sponges* (*Porifera*), 128 *Hydrozoa*, 63 *Anthozoa* and 6 *Ctenophora*.

Finally, 327 single-celled animals (*Protozoa*) are known, of which 121 *Foraminifera* and 74 *Radiolaria*.

It has been mentioned above that the fish fauna in the deep Davis Strait south of the submarine ridge from West Greenland and across to Baffin Land is of an entirely Atlantic character, and this also applies to lower animals, as, for instance, crustaceans and echinoderms. Also certain deep fiords of South Greenland are inhabited by species, which otherwise belong to the deep sea regions of the Atlantic, as among fishes the above-mentioned *Centroscyllium Fabricii* Reinhardt and *Raia spinicauda* Jensen. But other deep fiords of South Greenland contain species which they have in common with the Norwegian Sea Deep, such as the above-mentioned *Raia hyperborea* Collett. The explanation of this faunistic contrast must be looked for in the fact that in the former kind of fiords the "warm" water from Davis Strait enters the depths of the fiords below the cold Polar water, whereas the other kind of fiords are "cold," temperatures of about 0° occurring at the bottom, in all probability in consequence of the fact that by sub-marine ridges they are cut off from the warm water in the depths of Davis Strait.

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The author is indebted to Dr. A. Berthelsen for permitting him to reproduce the hitherto unpublished original photos, *viz.* figs. 9, 10 and 11, and to Dr. Knud Rasmussen for the original photos for figs. 5 and 6.

THE INLAND ICE

BY

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INTRODUCTION.

The ice-covered part of Greenland is calculated at 1,869,000 km² or about 86 per cent of its total area. This figure, however, is probably a little too high, as it has been proved by recent journeys in northernmost Greenland that there are considerably greater ice-free areas than have been taken into account in the latest estimations. By far the greater part of this ice-covered area is included in the continuous ice cap which is termed the inland ice; but outside this there are smaller local glaciations, partly entirely isolated ice caps, partly névés bordering on the inland ice and often entirely merged into it, though they do not receive alimentation from it. Also these local ice areas will be mentioned in this chapter as occasion offers.

The scientific interest in the study of the inland ice is associated with its enormous extent, and it depends partly upon the infinitude of glacial phenomena which present themselves along its 7000—8000 km circumference, the different sections of which are subject to rather different climatic and morphological conditions, and partly upon the resemblance which must be supposed to exist between the conditions of its existence and the conditions prevailing in northern Europe and northern North America during the glacial period. Therefore, both general glaciology and Quartenary geology have turned, and in the future will turn, to the infinite ice fields of Greenland for proofs of hypotheses already set forth and impulses towards fresh researches.

The knowledge of the most salient feature of the inland ice, *viz.* its enormous extent, is as old as our knowledge of Greenland. As early as in the "King's Mirror," which is supposed to have been written at the beginning of the 13th century, it is said that habitable regions are only to be found along the coast, all else being covered by ice. Also, at an early period the so-called ice fiords, in which the large icebergs form, attracted attention. On the other hand, it was long before any European ventured upon the inland ice itself.

In 1751 Dalager undertook the first ice journey, which led him to the nunataqs within Frederikshaab Iceblink, now called by his name. At first he found the ice as smooth as the streets of Copenhagen, only "somewhat more slippery," although on the other hand it "was not necessary to wade out towards the sides through the dirt for fear of being overturned by the horses and carriages of the postmaster," but later on progress became more laborious. Still, a long time was to elapse before Dalager found successors. In 1830 Kielsen ascended the "Iceblink" (a local ice cap) in the Holsteinsborg District and spent three hours there. He reports that "out at the margin, although on top of the ice, there lay a heavy stone which several people would not be able to lift, and which could not have been transported there by human hands," but it is a matter of course that this excursion did not tend to enlarge our knowledge. This also applies to Hayes' ice trip at Port Foulke (lat. 78° 20′ N.), *inter alia* because the fantastic distances stated (70 miles in three days!) weakens our confidence in the observations reported.

The scientific investigations of the interior of the inland ice were inaugurated by A. E. Nordenskiöld, who in 1870 penetrated 56 km on the ice in lat. 68° 20′ N. Then followed the ice journey of I. A. D. Jensen across Frederikshaab Iceblink to the nunataqs which were subsequently named after him, a distance of 75 km. In 1883 the great expedition of A. E. Nordenskiöld was completed, in the course of which he penetrated more than 100 km on the ice, and then sent his Lapp skiers ahead in order to reconnoitre; the latter according to their own statement penetrated 220 km farther, a distance which according to Nansen must be reduced to 65 km and, according to Quervain, to 105 km, the route of Quervain crossing the route of the Lapps and in the very altitude, about 1950 m, which the Lapps reported to have attained at the end of their journey.

In 1886 Peary began his series of ice journeys with a trip of about 150 km from the west coast in lat. 69½ N. Two years afterwards all records hitherto held were beaten by Nansen, who in lat. 64½ N. traversed Greenland, an expedition which not only demonstrated the possibility of travelling in the interior of Greenland, but also yielded abundant scientific results. Still longer was the route by which Peary, in 1892, twice crossed the inland ice of North Greenland, and this journey he repeated in 1895. In 1893 Garde undertook his well-known ice journey in the Julianehaab District, where the considerable altitudes attained are of particular interest.

In the present century the traversing of the inland ice has become an almost everyday occurrence, and we will consequently content ourselves with a brief survey: Ejnar Mikkelsen 1910, Quervain 1912, J. P. Koch 1913, Knud Rasmussen 1912 (returning to his starting point) and 1917, and Lauge Koch 1921. The results obtained by these expeditions will often be mentioned in the following.

Besides these expeditions across the ice nearly all the greater expeditions to the coast regions of Greenland have contributed towards our knowledge of the marginal zone of the inland ice. They will be mentioned elsewhere in the present work, and so we will limit ourselves to some few which are especially interesting. Among the old ship-expeditions we mention that of O'Reilly in 1817, which is well worth remembering because of his original conception of the ice cover. He thought that periods with a large cover of ice interchanged with periods without such covers, and that the reason was the change of position of the earth's axis. The sight of the huge icebergs, however, made him overvalue the rate of decrease of the present ice cover, as he expected that the waters of Greenland, within a measurable period, would be more generally and safely navigable, for which reason he thought fit "to add some observations regarding Disko Island, as it may hereafter stand connected with the concerns of British commerce"!

Graah's journey (1828—31) supplies various facts regarding the large glaciers of the east coast. Kane discovered the greatest glacier of the northern hemisphere, Humboldt Glacier. Further, mention should be made of the Danish expeditions of survey under I. A. D. Jensen, Ryder, Hammer, Garde, Moltke and others; of the investigations of the east coast undertaken by Holm, Amdrup, Ryder and the "Danmark" Expedition, as well as Steenstrup's, Helland's and Drygalski's minute studies of the ice in the central parts of Greenland, and those of Chamberlin and Salisbury in the northwestern regions.

In conclusion we must mention H. Rink, the man who first attracted the interest of the scientific world to the immense importance wich the study of ice conditions in Greenland might have towards understanding that inland ice, which at a geologically late period covered great portions of Europe and North America. Rink, who paid his first visit to Greenland in 1848 and lived there as a Government official from 1853 to 1868, has himself contributed to our knowledge of the nature of the inland ice by a number of accurate observations, as well as by discerning theories on the origin of the ice and the formation of icebergs. It is also Rink who first made use of the term "inland ice." The older writers most frequently use the term "ice blink", an allusion to the peculiar light which is seen to hover over the inland ice when approaching land from the sea. This name, as is well known, survives in Frederikshaab Iceblink, the name of the farthest projecting and, consequently, first visible lobe from the inland ice of South Greenland.

GENERAL OUTLINES.

In Melville Bay the inland ice stands forth in its full grandeur to the traveller approaching the country from the sea. Along the some 375 km long coast stretch from Cape York to Wandel Land the inland ice reaches

the sea in about seventy places and constitutes the coast for more than 300 km. According to Lauge Koch more than half of the total ice-front may be considered stationary, whereas the remainder bears the character of glaciers. Seven of these are more than 10 km in width, *viz.* the Steenstrup, Nansen, King Oscar, Peary, Holm, John Ross and Wulff glaciers. Icebergs derive particularly from the three former, as well as from Dietrichson Glacier, while most of the small glaciers are not productive of icebergs. From the point of view of scenery there is a considerable difference between the north and the south part of the coastal area of Melville Bay. Between Cape York and Cape Thalbitzer (long. 61°) the surface of the outermost 10—20 km of the inland ice is entirely determined by the underlying land, as if a thin mantle of ice had been spread over a wildly jagged rocky country. Large valleys and mountainous parts dimly glimmer forth in the interior; nearest the coast there are even suggestions of details in the surface relief of the mountains, and where there is a particularly steep mountain slope the cover of ice has burst, making the rocky ground appear in the light of day. Such a mountain, entirely or partly hidden by the ice, the Polar Eskimos call a *pingo*; in the southern part of Greenland the word *nunataq* is used for isolated mountain peaks or greater areas, which, like islands, project above the inland ice. When passing in the direction of the interior the surface of the ice gradually assumes rather an undulating character and, finally, at about 40 km from the coast, it is perfectly even. South of Cape Thalbitzer the horizon of the inland ice stands forth as a level line, above which only a few sharply defined and snow-bare peaks, *nunataqs*, rise. In the northern part of this section, where all the most productive of the glaciers of Melville Bay are to be found, the surface of the inland ice, according to Lauge Koch, rises to great heights, almost right out to the coast. From Steenstrup Glacier, great portions of whose central productive part float on the water, and farther south the inland ice is low, being about 400—500 m, far into the country.

In the Upernivik District, between the inland ice and the open sea, there is a fringe of islands, though a fifth of the total ice front within this district comes right down to the water. Among the largest glaciers can be mentioned Giesecke and Upernivik Glaciers. In the southern part of the district the islands pass into rather large land-masses which, like peninsulas, project from the ice-covered mainland, and this marks the beginning of a section of the contour of the inland ice, which is characteristic, in that the margin of the ice is situated far inland, and is separated from the coast by a border land, which in certain places is up to 150 km in width. However, about lat. 69° and 71° N., it is interrupted by the large bays, Nordost Bay and Disko Bay, which extend almost as far as the very margin of the inland ice, and into the innermost ramifications of which some of the mightiest of the glaciers of the west coast send forth their enormous production of icebergs. In Nordost Bay the most important of these so-called ice fiords are

Karrat Icefiord with Umiamáko Glacier, Itivdliarssuk and Qarajaq Fiord, and in the interior of Disko Bay we find Torssukatak and Jacobshavn Icefiord. But besides these and other lobes from the inland ice there are, in this area, an infinitude of glaciers, the névé areas of which are local accumulations of ice on the peninsulas and islands of the outer land. This area is more abounding in glaciers than any other area in the world. Thus Helland on the coasts of Kangerdlugssuaq Fiord (lat. 71° 20′ N.) counted no less than forty-seven glaciers, besides the huge one debouching into the head of the fiord. On the north side of Nûgssuaq Peninsula there are, according to Drygalski, along the 100 km stretch between Eqaluit and Niaqornat as many as twenty-three glaciers; besides, from the same glaciation area several glaciers extend towards the large valley tract, which passes right down through the peninsula.

With the increasing breadth of the outer land, our knowledge of the margin of the inland ice unfortunately decreases, because it is so difficult to approach it unless in a boat, and even the long fiords, in many places, do not reach the margin of the ice. In lat. 66° N. the so-called Sukkertoppen Icetongue comes almost right down to the outer coast. It is, however, not a lobe from the inland ice proper, but a number of coalescing ice caps, which owe their existence to the considerable mountain heights of these localities. In the Godthaab District many glaciers extend from the inland ice to the heads of the fiords, and at the southern boundary of the district, in lat. 62° 30′ N., the inland ice sends a huge lobe, Frederikshaab Iceblink, almost right down to the sea. Beyond a low, level sandy plain, only 2—5 km in width, the ice rises in a convex slope, the inclination of which is at the base 30°—50°, but quickly decreases. When ascending the ice tongue, Jensen, at a distance of 9.1 km from the margin, reached a height of 355 m which shows an average inclination of 2° 14′. In its outer part Frederikshaab Iceblink is nearly 20 km in width, but higher up, between a couple of nunataqs, it is contracted to barely 9 km. The margin forms a very regular arc, the position of which seems rather constant. The movement of the ice in the centre of the glacier Jensen determined to be about 3 m within the twenty-four hours.

South of Frederikshaab Iceblink the width of the coast land has shrunk to about 35 km which width it retains, until the coast—and so also the margin of the inland ice—in the Julianehaab District deflects towards the east. Here the foreland is to a higher degree dissolved into islands, and in many places glaciers from the inland ice come right down to the sea. West of Sermitsialik Glacier where, in 1893, Garde ascended the inland ice, the margin of the ice lay a little more than 300 m above sea level. From the glaciers in the interior of Sermilik Fiord very large and numerous icebergs are produced. West of the westernmost of the Sermilik glaciers the height

of the ice margin above sea level is, according to Garde and Jessen, rather varying, ranging between 250 and 500 m.

South of lat. 61° N. according to Holm and Garde, there is no continuous inland ice, but only more or less extensive local névés. Holm expressly states that the most pronounced features of the landscape are the mountainous parts and not the ice. In the southern part of the east coast, as far as Igdluluarssuk (lat. 63° 70′ N.), the mountains are so high that the inland ice cannot push down to the outer coast, but through numerous valleys it sends a large quantity of greater and smaller glaciers down to the long fiords. Only over a distance of some 35 km in about 62° latitude is the coast land completely covered by an undulating ice plain, here and there interrupted by nunataqs up to 1800 m high. Among the huge glaciers which here shoot out into the sea the 5200 m broad Puissortoq is known from of old as one of the most dangerous points to pass on the east coast of Greenland.

Between Igdluluarssuk and the Angmagssalik District the inland ice almost everywhere comes right down to the sea, partly in the shape of broad glaciers pushing out between tall, pointed nunataqs, partly as an infinite shining white level plain. But from about lat. 65° 30′ N. to Agga Island, two degrees of latitude farther north, the inland ice is separated from the sea by a 10—40 km broad ice-free coast land, which is broken, almost in the centre, by the huge glacier Ikerssuaq. According to Holm the two glaciers which extend into Sermiligâq Fiord derive from local névés. Along the distance Agga Island—Kangerdlugssuaq (about lat. 68° N.) the coast is very rugged; between tall, elongated mountains huge glaciers pour down to the coast and, at least as far as the northerly ones are concerned, out into the water, where they terminate in steep walls. The succeeding coast stretch, as far as Scoresby Sound, *viz.* Blosseville Coast, is for the greater part free from ice, but between Nunapisua and Cape Beaupré a number of glaciers pass right out into the sea.

From Scoresby Sound to the north end of Germania Land at lat. 78° approximately, the inland ice or lobes from it are not visible from the outer coast. In some localities, for instance on Hudson Land and Germania Land, as well as on some of the larger islands, Clavering Island and others, there are local névés, but glaciers deriving from the inland ice are only encountered at the heads of the large fiords and bays, in which this part of East Greenland abounds. In this connection it should be borne in mind that, according to J. P. Koch, Germania Land is in all probability an island, but the inland ice comes right up to its western margin, sending along the latter two huge glaciers—Kofoed-Hansen Glacier and Storströmmen—towards the north and south, respectively. The last-mentioned glacier terminates in the innermost part of Dove Bay, Berg Fiord, where it joins Bistrup Glacier in a steep wall of about 30 m above sea-level; the central part of the glacier floats on the water.

North of lat. 78°, in Jökel Bay, as well as in Seventy-nine Fiord, the inland ice pushes out into the sea as quite flat lobes, almost merging into the sea ice. Certain portions of the ice rest firmly on the bottom of the sea, while others float; where the fixed and the floating portions meet, pressure ridges appear, which owe their existence to the fact that the floating portions move up and down with the tide.

On Hovgaard Island there is a névé, which towards the east partly reaches the sea, and towards the west sends a couple of glaciers down into Dijmphna Sound. Also Lambert Land, Lynn Island and the peninsula Holm Land contain local névés, but between latitude 79½° and 81° N. the inland ice is blocked from the sea by a huge mountain tract; still, a couple of glaciers reach down into Ingolf Fiord. From Antarctic Bay to Northeast Foreland the ice has an unchecked passage to the sea, terminating here in a 10—15 m high steep wall "in derselben Weise wie die berühmte antarktische Eismauer" (Koch and Wegener). On the north side of Crownprince Christian Land where the sea ice never breaks up, the ice shoots out into the sea in a similar manner as in Jökel Bay, *viz.* as a flat non-calving lobe. Upon the whole the ice on Crownprince Christian Land is of the nature of an extensive névé; crevasses, melting hummocks and other characteristics of the marginal zone are lacking; only where the ice passes right into the sea does it form steep walls, whereas it gradually flattens at the transition to ice-free land. But here we are probably dealing with a local névé which towards the south-west seems to coalesce with the inland ice.

Along the north coast of Greenland there are considerable areas of ice-free land. On Peary Land local ice caps are met with, but the inland ice does not extend as far as that, and in North Greenland generally it only touches the sea at the heads of the large fiords, which cut far into the country and are continued behind the glaciers as depressions in the inland ice. Petermann Glacier, Ryder Glacier and several others are among the largest glaciers of the northern hemisphere, but they are all inferior in size to the more than 100 km broad Humboldt Glacier, which with a 100 m high front extends into the sea in Kane Basin.

On the peninsula between Kane Basin and Inglefield Gulf there is, along the north coast, a 20—40 km broad strip of ice-free land in front of the inland ice, which covers the south part of the peninsula, apart from a few of the smaller peninsulas such as Red Cliff Peninsula *et al.* containing local ice caps. Also the peninsulas between Inglefield Gulf and Olrik Fiord and between the latter and Wolstenholm Fiord, as well as Herbert Island, Northumberland Island and several others, are covered by local ice caps, and the same holds good of the area behind Cape York, from which 13 glaciers push down across Crimson Cliffs; this area is divided from the inland ice by a depression filled by Pitugfik and Wulff Glaciers. Along the whole of the distance, Inglefield Land—Cape York, numerous glaciers come down

to the sea. Among the largest are the united Tracy-Farquhar and Melville Glaciers in Inglefield Gulf, Moltke Glacier in Wolstenholme Fiord and Pitugfik Glacier. As compared with the large glaciers of Central Greenland none of these are particularly productive.

SNOW LIMIT AND FORMATION OF ICE.

The Snow limit. By the climatic snow limit we understand the altitude above which some of the precipitation on a horizontal surface remains, in the form of snow, from one year to another. The actual or topographic snow limit rarely coincides with the climatic, the form and exposition of the surface now enabling the snow to last over the summer in altitudes below the snow limit, and now precluding the accumulation of snow in higher altitudes. The shorter the summer, the greater the influence of local conditions, the more variable the topographic snow limit, and the more difficult the determination of the climatic one. The latter is, therefore, almost impossible to indicate in the case of Greenland—and of course notably North Greenland—all the more as only very sparse information is at hand regarding the former.

The snow limit in South Greenland, according to Garde, lies at an altitude of 2000—3000 ft. or 640—960 m; from his description, however, it seems as if the latter figure is more correct. At Frederikshaab Iceblink the snow line seems to lie at a similar altitude, but Kornerup draws attention to the fact that the theoretical snow limit is very difficult to define, as the topography is of far greater importance to the melting off in a country like Greenland, where the rays of the sun hit the surface at a very acute angle, than in more southerly regions. Also, the amount of dust on the ice plays a part in the melting of the snow, a considerable quantity of dust causing a quicker melting. In about lat. 69° Quervain found the snow limit on the western side of the inland ice at 1450—1500 m above sea level, and a similar high altitude, *viz.* between 1100 and 1600 m, seems to be suggested by the indications of Nordenskiöld from his ice journey. In the neighbourhood of Qeqertaq, on the south side of Nûgssuaq Peninsula (lat. 70° N.), Engell estimated the altitude of the snow limit at a little more than 700 m above sea level. On the north side of Nûgssuaq Peninsula Drygalski finds the snow limit at an altitude of 860 m, in this locality coinciding with the 0° isotherm of the warmest day. On the same coast stretch Helland, for three points, gives 970 m, 800 m and 760 m respectively, but, like Kornerup, he maintains that it is the local conditions which make the altitude of the snow limit so varying; at Upernivik Island he found, even in August, on the sea ice year-old snow, which was shortly afterwards increased with new snow, so that it may be said with certainty that the snow in this place can

remain from one year to another at sea level; on the other hand, a plateau on the south side of Upernivik was free from snow at an altitude of 890 m.

According to J. P. Koch similar conditions were encountered on the east coast in lat. 77°—79° N. where, on the west side of Schnauder Island, he found an accumulation area on the sea itself and on Ile de France a névé reaching the level of the sea. On the mainland the snow limit increases in the direction of the interior; in the northern part of Germania Land it is found at 300—500 m, east of Anneks Lake at about 700 m and at Ymer's Nunataq at 900—1000 m. Farther north, on Crownprince Christian Land (lat. 81°—82° N.) the névé area of the inland ice(?) extends as far as the sea. On the other hand, Quervain at about lat. 66° N. puts the snow limit on the east coast at 1000—1100 m.

At a local ice cap near Cape York Salisbury determined the altitude of the snow limit at 1000 ft. (320 m), but he supposes "that the lowness of the snow line here must be the result of local meteorological conditions." Round Inglefield Bay he calculates its altitude at twice this figure, and in many places north of Melville Bay he is of the opinion that it is at 2200—2300 ft. (700—730 m). A far higher position seems to appear from Freuchen's observations in lat. 79° N. when he says[1] that only at 1350 m above sea level "is it possible to assert with any confidence that the snow covers the ice all the year round."

Everything considered, it seems that the snow limit becomes somewhat lower from south to north, and this in spite of the fact that precipitation decreases in the same direction. The lowest position is found in northern East Greenland, where the snow limit is locally at the level of the sea. The—unfortunately rather sparse—observations further tend to show that it is lower on the southern part of the west coast than north of the Arctic circle, which is probably due to the fact that precipitation is comparatively great in South Greenland. Also, it seems as a rule to be lower in local glaciation areas on the outer land or islands than on the inland ice. This undoubtedly has some bearing upon the fact that the prevailing winds blow from the interior of the inland ice in the direction of the coast, and they carry considerable masses of snow, so that outside the inland ice a greater quantity of snow is deposited than is represented by the local precipitation proper, while, conversely, the accumulation of snow on the inland ice is diminished.

Snow-drift Glaciers. In some places, which are sheltered but lie below the climatic snow limit, snow accumulates in drifts of such dimensions that the raised summer temperature cannot make away with them; these drifts then gradually pass into ice, and in that manner an actual névé or—should

[1] M. o. G. LI, page 345.

it be that such a snow drift is formed on a steeper slope—a glacier arises. Koch and Wegener investigated such snow-drift glaciers, as they call them, on Germania Land, where they are very common. The snow limit is here at an altitude of 300—500 m, and nearly all of the snow-drift glaciers are below this altitude, a single one even at the very level of the sea. The amount of precipitation was at "Danmark" Harbour in two winters 143.5 and 147.4 mm respectively, but in the spring of 1908, on the Gnipa Cave Glacier, which will be mentioned below, and which lay at an altitude of 50—150 m, the thickness of the new snow was measured at 3.61 m, corresponding to a water layer of 1552 mm or more than ten times the annual precipitation.

Such a snow-drift glacier frequently, for a short distance, fills a valley through which a brook is flowing. The brook then flows into the glacier from above, and continues its course under it, in which manner a cave is formed, extending throughout the glacier. A particularly large and beautiful example of this, with glorious stalactite and stalagmite formations, has been described in detail by Koch and Wegener under the name of Gnipa Cave. It is about 900 m long and forked at the upper end, where a lateral brook debouches into it.

Similar permanent accumulations of snow below the snow limit occur, according to J. P. Koch, on Peary Land and in Flemming Inlet, north of Scoresby Sound; also in Northwest Greenland they seem to be very common. Chamberlin calls them "fringing glaciers," and some of those which have been described by him constitute a transition form to ordinary glaciers, as, for instance, the small glaciers on Northumberland Island, of which he writes that "their gathering grounds seem to be chiefly in amphitheatres at the heads of valleys— — —combined with an inflow from the plateau surface above. The accumulation of snow is perhaps more due to the lodgment of the wind drift in the amphitheatres than to direct precipitation." Salisbury calls them "cliff glaciers," since both they and their feeding grounds are on the faces of cliffs. Here it is a question of actual glaciers with glacier motion and deposing considerable moraines in front of their ends.

Origin of the Inland Ice. At the present time hardly any one will doubt that the inland ice was originally a formation of great heights, névés arising in the higher mountain regions when the climate became sufficiently cold; afterwards they increased in size and, in the form of glaciers, extended still farther into the valleys, till these were filled with ice, and the former numerous isolated névés grew together into a few larger ones and, finally, into a single continuous ice field, above which only isolated peaks projected, until also they, in the central parts, were buried under the constantly increasing ice cover. The thickness of the latter, undoubtedly during as well as after the ice age, has been varying, which variations have involved

changes in the position of the ice margin. As far as can be discerned, the ice margin is now in the main stationary, and this in its turn means that the supply of water, which the inland ice receives through precipitation, is as great as the amount carried away by the water courses in the shape of icebergs and through evaporation. It is, however, a problem to what extent the presence of the ice contributes to the maintenance of this balance, or in other words whether, if the ice might be imagined to have been removed, a new inland ice would form in Greenland and, if so, attain its present thickness. This purely climatological problem will, however, not be dealt with here.

It is well worth remembering how Rink, the pioneer of the research of the inland ice, conjectured it to have been formed. He observed that many of the rivers which flowed all the year round, particularly those which in their lower course flowed over level plains, in winter deposited a crust of ice on the underlayer, stemming the water till it could flow across the ice crust; then a new crust having been deposited on the one first formed, the water was again stemmed, and so forth. Thus, in the course of the winter, ice layers were formed in certain places, and the thickness attained was so great that they could hardly be thawed by the summer heat. Supposing that only a little more ice is formed in winter than can be done away with in summer, the possibility of the formation of a steadily increasing layer of ice is, as a matter of fact, at hand. Ice formations of this kind and existing through several years have been observed in various places in Greenland, as, for instance, by Drygalski. Rink now imagined that such ice formations at the delta areas of rivers increased farther in along the valleys and, gradually filling them, extended above the water divides and were fused with the ice formations in other valley systems, until, finally, after receiving supplies from névés formed through the precipitation of the snow, they buried even the highest mountain tracts. Rink thus regarded the inland ice as a formation which had been built up from below, whereas modern glaciology regards it as a highland formation which secondarily has filled also the lower regions of the country.

HEIGHT AND SHAPE.

As to the altitudes of the inland ice, the journeys made across it have supplied us with sparse, but therefore not less valuable information. As far as the central parts are concerned, it is only from the three journeys from coast to coast, Nansen's in 1888, de Quervain's in 1912 and J. P. Koch's in 1913, that we have learnt something of the topographical conditions. To this must be added the numerous voyages undertaken in northern Greenland across the inland ice by Peary, Knud Rasmussen and Lauge Koch between 1892 and 1923, while more or less broad marginal zones are known,

particularly through the ice wanderings of I. A. D. Jensen, W. Garde, A. E. Nordenskiöld and Ejnar Mikkelsen.

Based upon the determinations of altitudes made in the course of these expeditions, Lauge Koch as well as A. de Quervain have attempted to give comprehensive cartographic accounts of the altitudes of the inland ice. Their two maps which are reproduced in figs. 1 and 2 deviate, as it will appear, on essential points. Lauge Koch is of the opinion that—apart from a small local centre of glaciation north of Angmagssalik—there are two maxima of heights or centres of glaciation on the inland ice, *viz.* in lat. 65° and 73° N. approximately, whereas Quervain reckons with three maxima *viz.* besides the southern maximum, which coincides with that of Koch and which, according to Nansen, must lie slightly north of the route followed by him, one in lat. 70° and one in lat. 76° N. approximately.

Fig. 1. Altitudes of the inland ice according to Lauge Koch.

The greatest heights passed by the three expeditions which traversed the country under the command of Nansen, Quervain and J. P. Koch, were in a direction from south to north 2720, 2500 and about 3000 m respectively. These very figures show that the ice does not slope down in all directions from one single centre, but that there are at least two maxima with an intermediary depression. On the other hand the—roughly speaking—regular and slightly inclining surface of the inland ice is such a characteristic feature that there would be nothing surprising in the fact that even the extremely long (about 2400 km) profile from north to south only had two maxima. Nor does Quervain attempt to prove why there should be three centres; he only writes: "La traversée danoise[1] nous semble faire soupçonner mème une troisième centre au nórd de cette itinéraire[2]." Judging by the material at hand there does not in reality seem to be anything to prevent combining the two northern maxima into one. But even if this is done, there is a marked difference between the maps of Lauge Koch and Quervain.

On his passage across the inland ice Quervain did not content himself with determining—by means of a barometer—the altitudes of a great number of points, but from each camping site he further, by means of a

[1] viz. J. P. Koch's journey, 1913.

[2] M. o. G. LIX, page 108.

theodolite, undertook a series of observations of the altitude of the horizon, at the same time making a note of the estimated length of the sight. In this manner he has succeeded in making a picture of the sloping of the ground which must be supposed to be essentially correct. It is true that Lauge Koch is rather doubtful as to the value of this method[1], in view of the very short sights — 0.8 — 4 km — which are instanced by Quervain, but when, on the one hand, considering the already mentioned evenness and regularity which characterizes the surface of the inland ice and, on the other, the harmony existing between the observations of de Quervain from one camping site to another it seems reasonable to suppose that his main result is in accordance with reality. This main result is that the route of the Swiss Expedition, roughly speaking, lies on a slope inclining towards the south or, in other words, on the slope of a maximum situated to the north of the route.

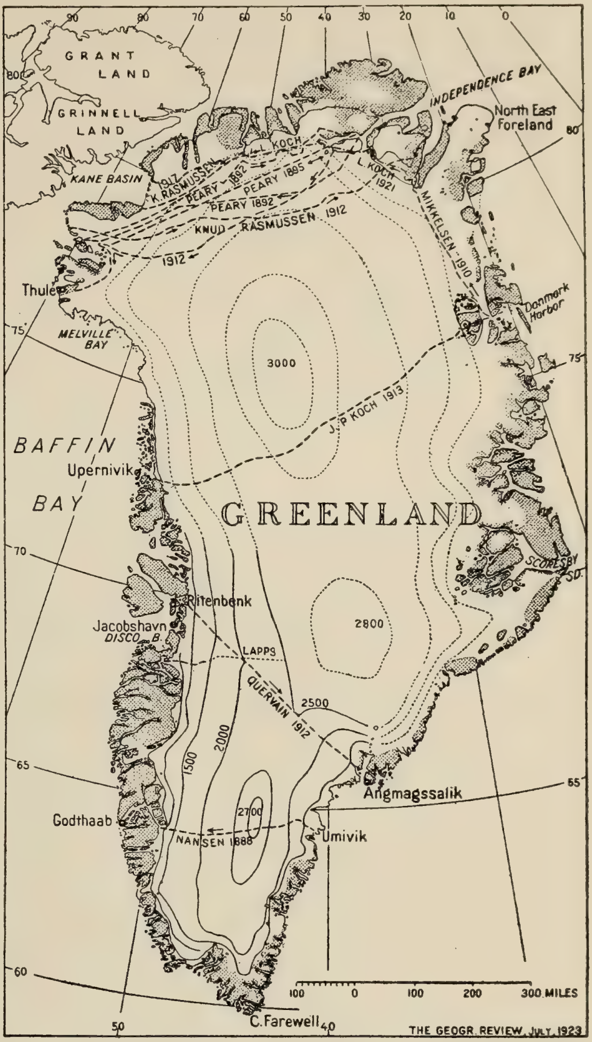

Fig. 2. Altitudes of the inland ice according to A. de Quervain.

In direct opposition to this, Lauge Koch, whose treatise "Some New Features etc." was written in Greenland at a time when he knew nothing of the publication of Quervain, is of the opinion that the route of the latter is along the northern slope of the southern maximum, or follows the very depression between the southern and the northern maximum. Lauge Koch's

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[1] Geographical Review XIV, 1924, page 175.

map is drawn in agreement with his hypothesis that the whole of the Greenlandic gneiss plateau has broken right across, along a line or a small zone from Disko Bay to the region south of Scoresby Sound, according to which hypothesis the two gneiss planes have been tilted in such a manner that each of them now has its greatest elevation towards the south and, from there, slopes towards the north. This is not the place to enter, in detail, into the geological and geographical justification of the hypothesis, except in so far as it bears upon the altitude of the inland ice. In order to determine more accurately the position of the depression which there must be between the routes of Nansen and J. P. Koch, Lauge Koch has constructed two profiles of the heights of summits on the west and east coast respectively, and these profiles show a decrease of the height from the south end of Greenland to lat. 70° N. approximately, then a steep rise and again a gradual decrease as far as the north coast. On the east coast there are, however, certain irregularities. Lauge Koch himself draws attention to the very elevated mountainous tract in the region near Angmagssalik, which he is most inclined to regard as "a horst moving independently of the rest of Greenland." On the other hand, he entirely neglects the pronounced depression of the profile south of the Angmagssalik area, which feature seems to harmonize with the existence of a depression south of Quervain's route. Everything considered our present knowledge of the altitude of the inland ice thus seems insufficient to yield a support for the hypothesis of a depression in connection with a fault zone right across Greenland and uniting the basalt area of the west coast with that of the east coast.

It has already been mentioned that Nansen passed the highest point of the route well to the east of the centre line of the country, and this also applies to Quervain's expedition, whereas the highest point on J. P. Koch's route lay considerably to the west of the centre line, *viz.* in long. 43° W. and lat. 74° 40′ N. In North Greenland the maximum height again seems to lie a little nearer the east coast than the west coast.

In the greater part of North Greenland the margin of the inland ice lies at a height of about 500 m above sea level. From this height the ice only rises slowly, so that comparatively large areas lie below 1000 m. This contour is rather irregular, the great fiord glaciers continuing as depressions far into the inland ice. Between the 1000 m and 2000 m contours there is generally a distance of more than 200 km, whereas J. P. Koch, in lat. 73° N., reached a height of 2000 m at a distance of about 60 km from the western margin of the inland ice. At Quervain's place of ascent in about lat. 70° N. the ice margin lay about 600 m above sea level, and already at a distance of about 20 km the height of 1000 m was passed, while the height of 2000 m was only reached about 180 km from the ice margin; on the east coast, however, the 2000 m curve only lay about 100 m inside the ice margin, the height of which was here 800 m. West of Jensen Nunataqs the inland ice

reaches a height of 1325 m. The distance from the nearest land is about 30 km, but the distance from the margin of the Frederikshaab Iceblink towards which, in this place, the ice is moving, is over 70 km. Between a height of 760 m and 1280 m the inclination was on an average 0° 47′, varying between 0.39′ and 1° 9′. Farther out towards the margin the inclination naturally becomes greater, being 2° 14′ between 0 and 350 m. In comparison it should be mentioned that in about lat. 61° N. at Sermilik Glacier Garde found an inclination of 4° 5′ from sea level to 1250 m and right up to his highest point, 2220 m above the level of the sea, the rise exceeded 0° 50′. The height of the ice margin Garde gives as 100 to 300 m for the east to west coast stretch west of Sermitsialik, while farther east it rises with the country, and along the north side of Ikerssuak it approaches 600 m.

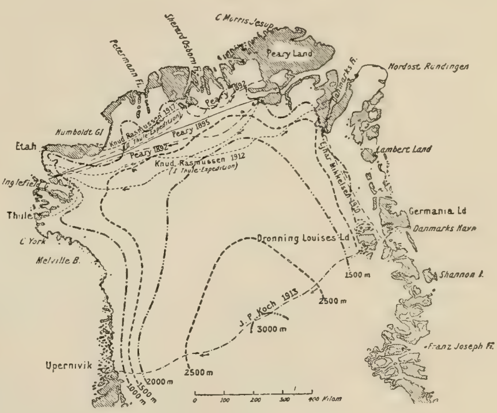

Fig. 3. Altitudes of the ice in North Greenland (Lauge Koch).

Even apart from the inequalities of the marginal zone (crevasses, melting hummocks, etc.) the vaulting of the inland ice is neither quite regular nor continuous. Nansen mentions two kinds of "waves," both passing very nearly in a direction north to south, partly larger waves, which in the main occur near the coasts, particularly the east coast, partly smaller, which are met with everywhere, but which also are rarer and less marked in the interior. The former he considers a reflection of the forms of the underground, to which it must, however, be observed that there is nothing in the geological structure of the outer land to suggest a north to south direction of the main topographic elements. The smaller waves, on the other hand, he supposes to be connected with the strong winds which blow from the interior towards the coast. Quervain mentions similar waves or "steps" (*gradins* as he calls them), and he also regards the larger as occasioned by the irregularities of the underlying land. On the west side, along a distance of 150 km, he counts ten of these steps between the margin of the inland ice and a height of 1800 m. Then between 1830 and 1930 m follows a pronounced "plain," which is particularly interesting, because Nordenskiöld's Lapps 20 to 30 km farther south reported a similar plain, assigning, it is true, a perfectly improbable extent to it. On the continued march towards the east Quervain passed four more steps of this kind, until he reached a height of 2200 m, from which there was a gradual rise up to the maximum height

of 2500 m. The divide itself is rather pronounced, and 50 km to the east of it there is again a plain at a height of about 2300 m and with a breadth of 12 km. At heights of about 1400 and 1650 m pronounced waves are once more met with, while at a level of 1300 m there is again a stretch with a very slight fall, followed by a steeper slope towards the margin.

The scientific problem which is most intimately bound up with the knowledge of the altitudes is the question of their origin. In the present case the question can also be put in the following manner: Is the surface form of the inland ice in the main determined by the form of the underground, or is it the physical properties of the ice, in connection with climatic conditions, which are the determining elements? The answer given to this question is of the very greatest importance to the problem of the origin of the inland ice. For if the answer be that the form of the underlayer is of decisive importance or, more particularly, that the great altitude of the inland ice permits one to draw conclusions as to the comparatively great height of the underlayer, it is evident that for the very formation of the ice essential importance must be attached to the altitude of the underlying country and its influence on temperature and precipitation, whereas this support will be lacking, if the form of the ice can be explained by its physical properties only. Finally there is of course the possibility that the external topographical and the inner physical conditions may both have played a great part in determining the form.

The point of view, which may be termed the topographic, is perhaps most distinctly expressed by Hess, when he writes [1]: "Where an extensive plateau of a faintly convex form projects above the snow limit, it becomes an area for the collection of an inland ice." Thus, he simply presupposes that the faintly convex surface of the ice reflects an underlying land of a similar form. On the other hand, Nansen ascribes to the plastic properties of the ice a paramount influence on the surface form without, however, neglecting the influence of the topography of the underground. A. M. Hansen arrives at the result that the profile of the inland ice along Nansen's route very nearly coincided with the arc of a circle, the radius of which—the curve of the earth's surface being left out of consideration—was 10382 km, and this mathematical regularity Nansen considered as proof that the thickness of the inland ice was so great that the form of its surface only in a very slight degree was dependent on the form of the underground, but was mainly due to the plasticity of the ice. In this connection, Nansen calls attention to Sir William Thomson's formula of the cross section of a plastic mass which may spread freely over a level underground:

$$\frac{x^2}{a^2} + \frac{y^4}{b^4} = 1$$

[1] Handwörterbuch der Naturwissenschaften, article ,,Eis".

where a is the radius and b the height of the vaulted mass, the formula denoting an ellipse-like curve. That the cross-section of the inland ice does not agree with Thomson's formula is, in the opinion of Nansen, due to the fact that its underground is very far from being a regular, not to say a level plane. But there is nothing to prove that its cross section would then approach another—one might feel tempted to say—still more regular mathematical curve, *viz.* the arc of the circle. As further evidence of the influence of the underground Nansen regards the fact that the highest part of the inland ice is not situated in the centre of the country, but somewhat farther east. If the ice cover only had a small thickness, the divide of the inland ice would coincide with the water shed of the underlying land. If, on the other hand, the thickness of the ice was extremely great as compared with the inequalities of the underground, the divide of the ice would come to be situated almost in the centre of the country. Now, the divide of the ice has been shifted towards the east, but still Nansen is of the opinion that the thickness of the ice is too great to allow of a direct conclusion to the effect that the water shed of the solid land is situated directly below the divide of the ice; it may very well lie a good deal farther east. For if the original water shed lies east of the centre line of the country, this will check the movement towards the east within the deeper layers of the ice, while the latter, without any obstacles, may float away towards the west, and so the divide of the ice will be shifted in an easterly direction. Nansen, however, also hints at the possibility that a greater amount of precipitation on the east side as compared with the west side may contribute towards the divide of the ice being moved in an easterly direction.

But Nansen did not content himself with analyzing the profile which he followed. Based on the sparse information, gathered in the course of the short trips, which until then had been undertaken on the inland ice, he considered himself justified in characterizing the form of the inland ice in the following manner: "The surface of the ice may be compared to a shield tapering in a southern direction, the surface of which is vaulted transversally as well as longitudinally. The transversal curvature coincides with arcs of circles, the radius of which increases at an unproportional rate from south to north."

Quervain maintains that the profile along the route followed by him has the same symmetrical form ("d'une régularité presque géométrique") as that of Nansen and, therefore, considers himself entitled to speak of a "type de profil de l'inlandsis." Also on this route the height maximum proved to be situated at a fair distance from the centre of the country, which fact Quervain, like Nansen, ascribes to the influence of the underlying land, all the more as 100 km from the east coast he saw the very high mountain country which he christened Schweizerland, and which contained Mt. Forel, the highest summit of Greenland (3440 m).

On the strength of the profiles of the inland ice drawn by Quervain and Lauge Koch, Meinardus has made an attempt to determine its "normal form." He constructs, in the usual manner, the hypsographical curve of Greenland, and it then appears, firstly, that this curve is convex upwards, in contrast to the hypsographical curves of all continents, which turn the concave side upwards. It is an expression of the fact that areas with high altitudes occupy the greater part of Greenland, whereas the lowland dominates in the ice-free parts of the world; in Greenland 41.8 per cent of the area lies between 2000 and 3000 m and only 7.3 per cent below 200 m, whereas the corresponding figures for the land masses in their entirety are 3.7 and 35.9 per cent. But Meinardus further succeeded in proving that the hypsographical curve of Greenland, for the whole of the interval of altitudes between 800 m and 2700 m, coincides very closely with a parabola, the axis of which is 80 m above sea level, and the formula of which is: $(y—0.8)^2 = 774.3—42.54\ x$, where y is expressed in hectometers, x in 100,000 km². That the highest and the lowest parts of the curve do not follow the parabola, but form segments of curves with the concave sides upwards, has naturally some connection with the fact that the highest points, as well as the greater part of the lower coast land, do not make part of the ice, but of the solid rocky ground and, therefore, approach the common continental type as to the extent of the different stages of altitude.

At the same time Meinardus determines the mean altitude of Greenland at 1650, and of the inland ice at 1900 m, which figures are far above those occurring in the continents: Asia 940 m, Africa 750 m, Australia 350 m, Europe 300 m, etc., the continents as a whole 700 m. When starting from the hypothesis that the hypsographic curve of the firm underground has a similar form to the one otherwise typical of all land, and roughly estimating its mean altitude at 500 m—*viz.* almost the same as that of Norway—the average thickness of the ice may be estimated at approximately 1400 m.

If one imagines that this ice cap, the hypsographic curve of which is a parabola, has a circular ground plan, and that the isohypses form concentric circles round its apex, the surface takes the form of a rotation ellipsoid, the cross section of which has the formula $\frac{r^2}{761.2^2} + \frac{(y - 0.08)^2}{2{,}783^2} = 1$ where r is radius in an isohypse circle with the area x km² or $r = \sqrt{\frac{x}{\pi}}$. It is this hypothetical surface form which Meinardus characterizes as the normal form of an inland ice, as he thinks it possible to set up a similar formula—only with other constants—for the antarctic inland ice.

This formula and the curve which it indicates greatly approaches the Thomson curve, which has been given above. The difference only is that the

ellipse formula contains the ordinate in the second power, whereas the Thomson formula contains it in the fourth, that is, the Thomson curve in the marginal zone is more strongly vaulted than the ellipse, but is otherwise flatter. If the Thomson equation would really apply to a mass of ice whose form alone was determined by its plasticity—the constant supply and waste of snow and ice being presupposed—the deviation must be taken as an indication that there are also other influences at work in the case of the inland ice of Greenland. For instance, the inequalities of the underlayer might bring about a check in the outflow of the ice, which in its turn caused the surface to be raised in the central parts. But the very fact that the surface form of the inland ice can be expressed in such a simple formula, makes it "extremely probable that it is in the main the very properties of the ice which determine the broad features of its surface form. [1]"

SURFACE FEATURES.

Aspect of the Ice front. As already suggested in the introductory chapter the ice front varies greatly, its aspect being dependent upon the climate as well as upon whether the ice is bounded by the sea, the outer land or a nunataq. Finally, at the margin of the inland ice proper with its almost imperceptible movement, conditions are naturally very different from those occurring at the edge of the relatively rapidly advancing glacier lobes.

Where the ice extends into the sea, it generally ends in a vertical wall, the height of which above sea level varies between under one metre and over a hundred metres. At Upernivik Glacier the greatest altitude measured by Ryder was 110 m, while Great Qarajaq, according to Drygalski, attains 100 m; on the east coast the greatest altitudes of glacier fronts, *viz.* at Puissortoq and Steenstrup North Glacier seem to lie between 50 and 65 m. Where the ice extends into a constantly frozen sea, as is the case in many places in North Greenland, it forms quite a flat slope, and this holds good of the inland ice proper as well as of glaciers; examples of the former from Jökel Bay and Crownprince Christian Land and of the latter from Petermann Fiord and Sherard Osborne Fiord have already been mentioned in the preceding.

Where the inland ice proper is bounded by the outer land, the extreme portion generally forms a vaulted plane, the inclination of which may be so slight that one can easily drive up the ice in a dog sledge, but which, on the other hand, may also be so considerable that it is impossible to ascend it. In certain localities entirely vertical terminal planes are also met with which, at any rate in South Greenland, indicates a stronger motion. J. P. Koch and Wegener state— without, however, entering in detail into

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[1] Meinardus, page 103.

the possible causes of the phenomenon—the peculiar differences offered by the ice margin west of Germania Land. North-west of Anneks Lake in lat. 77½ N. there is, in front of the ice margin, a large irregular moraine landscape, whose clay and gravel masses in many places cover "dead" ice, and which in the southern part passes quite gradually into the inland ice, while the latter, farther north, ends in a vertical wall 30 to 40 m in height, from which there are from time to time considerable ice slides. About 50 km farther south a small glacier pushing down into Sæl Lake, offered the possibility of ascending the ice, which north as well as south of it formed a steep front 15 to 20 m high. In this place, however, we are not strictly dealing with the inland ice but with the lateral margin of a huge glacier, Storströmmen, whereas the southern part of the "moraine landscape" lies off a stationary zone between Storströmmen and Kofoed Hansen Glacier, which extends towards the north. On Crownprince Christian Land where the actual névé area comes right down to the level of the sea, J. P. Koch and Wegener describe the ice margin in the following words: "Steilwände gibt es nur da, wo das Eis in das offene Meer hinaustritt. Dagegen ist der Übergang zum eisfreien Land ein ganz allmählicher, mit sanften Abhängen, etwa wie bei Schneewehen. Zwischen der Nordost-Runding und dem Nakkehoved, wo ein ganz schmaler, eisfreier Strand vor dem Eise liegt, bildet der Eisrand allerdings einen etwas steileren Abhang, der aber doch nirgends steiler ist, als dass man mit Hundeschlitten hinauffahren könnte."

Lauge Koch describes the fully 200 km long ice front on Inglefield Land as extremely monotonous, particularly within the westerly section. In two places, slightly west of long. 70° W. and about lat. 67° 30′ N. there are proper glaciers, and immediately south of the latter the ice margin, along a north to south stretch, forms a vertical wall, some 100 m high and many kilometres long; in several places large pieces of ice fall down on the land, and the ice margin here seems to be moving somewhat. Otherwise the ice margin most frequently rises with a gradual slope above the land, which here is 200 to 300 m above sea level. The 100 to 150 m nearest the bottom are steepest, with inclinations from 20° and upwards; then the surface slopes less steeply, but still rather quickly up to about 1000 m. Crevasses hardly occur at all.

Where the inland ice borders upon nunataqs, a number of characteristic phenomena become visible. At the western margin of Jensen Nunataqs, above 1250 m above sea level, the ice, according to Kornerup, had a convex surface, inclining 15°—40° towards the nunataqs, but on the east side where the ice moved in the direction of the land, its surface was frequently plane right up to the nunataq, lying here at a level of about 1575 m. In some cases the whole of the nunataq lay in a funnel-shaped depression in the inland ice, sometimes even in such a manner that the summit was lower

than the surface of the surrounding ice (fig. 13). Ryder mentions examples of the same from Upernivik District. The reason for the phenomenon these two authors find in the fact that the rocky ground is partly more strongly heated than the ice by the rays of the sun, and partly throws back the latter, so that the ice round a nunataq is subject to a strong melting-off process, even at a considerable altitude above sea level. Entirely the same result is reached by Chamberlin when he says that the ice, in many instances, does not crowd against the sides of the nunataqs, "but is melted back, leaving a moat-like ditch between the eminence and the mass of the glacier surrounding it, not unlike the defensive trench of an ancient castle. Still, whenever the motion of the ice is considerable, this intervening space is absent and the ice impinges forcibly upon the base of the prominence [1]."

On the other hand, Nansen expressly states that the surface of the ice on the east coast generally does not slope down towards the nunataqs, indeed, in some places it seems as if the ice rises towards the nunataq, and in his opinion the reason for the difference between the east and west side of Greenland is merely to be looked for in the fact that the ice on the west side is in rather strong motion, whereas on the east side it is very nearly stationary. This opinion which is thus directly opposite to the one set forth by Kornerup and Ryder, he bases, *inter alia*, upon the fact that a viscous mass which is in motion, as for instance a glacier, generally has a vaulted surface sloping down on both sides. In the case of valley glaciers the movement is strongest in the centre, whereas to the sides it is checked by friction against the sides of the glacier bed. If now it was this circumstance which made itself felt at the margin of a nunataq, it was to be expected that the steepest ice slope would be where the ice moved parallel to the margin of the country, or where, in other words, the greatest differences of speed made themselves felt, but at Jensen Nunataqs the phenomenon was most pronounced on the lee side, where there was generally a small lake between the nunataq and the ice. Further, it is correct that the cross-section of the surface of a glacier is generally a convex arc, but the actual lateral front is very frequently a vertical or even a slightly overhanging wall, and it is then quite unintelligible that the upper layers, which thus must have a movement directed towards the side of the valley, should not come quite close up to the latter, unless it be the melting-off, caused by the heat radiated or thrown back from the mountain slope which keeps the ice at a respectful distance from the valley side. Therefore, Kornerup's explanation seems to be correct as far as the nunataqs of the west coast are concerned, while it is still an open question why conditions are different at the nunataqs on the part of the east coast visited by Nansen. Drygalski, who saw nunataqs

[1] Journal of Geology, III, 1895, page 568.

of the "west coast type" in the background of Ũmánaq Fiord, explains the difference to the effect that East Greenland is the accumulation area of the ice, where the precipitation surplus is sufficient to compensate for the melting-off, caused by the heat radiated from the sides of the rocks. The nunataqs mentioned by Nansen are situated at a height of about 1000 m, but our knowledge of the situation of the snow line is too deficient to enable us to determine whether Drygalski's explanation can be the correct one. The nunataqs drawn by Garde [1], with the ice sloping upwards in a similar

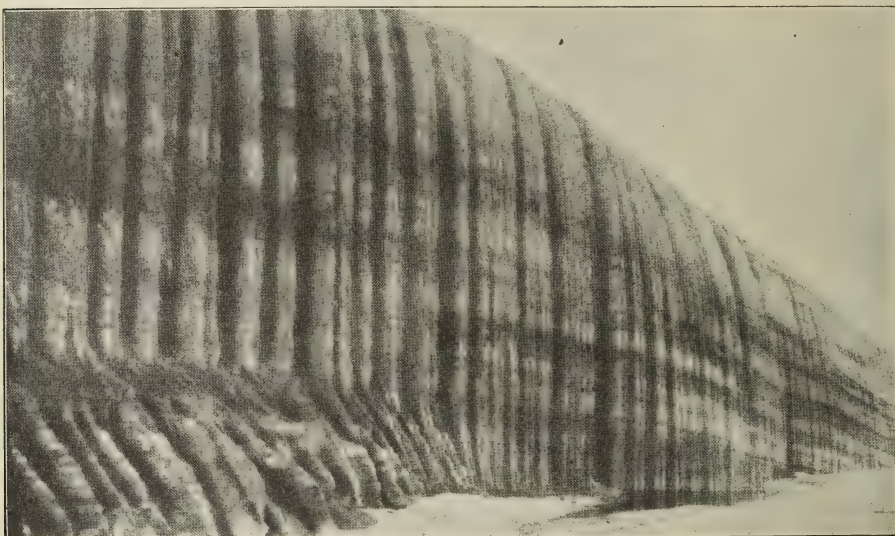

Fig. 4. The furrowed ice wall at Ymer's Nunataq (J. P. Koch and Wegener).

manner as on the east coast, are situated about 1550 m above sea level, that is, at any rate considerably above the snow line.

In lat. 77° 25′ N. the "Danmark" Expedition visited a nunataq which was named Ymer's Nunataq. The ice front here presented several peculiarities, which are described in detail by J. P. Koch and Wegener. Everywhere along the margin of Ymer's Nunataq the inland ice forms a steep wall, at the base of which there is a chain of marginal lakes. On the north side the ice wall, though steep, was not perpendicular, and the valley between it and the slope of the rock was 200 to 300 m in breadth. On the east side the valley was only about 30 m broad, and the ice wall in this place was perfectly vertical up to a height of 20 to 40 m, above which there was a more gently inclining portion. A characteristic feature of this steep wall is first its total lack of crevasses, which seems to indicate a crowding of the ice mass here at the east end of the nunataq where the two ice currents along its north and

[1] M. o. G. XVI, table III.

south sides meet. Then the ice wall, as shown in figs. 4 and 5, was greatly furrowed. Between the furrows sharp edges projected, now with obtuse, now with acute angles and with a mutual distance of about 1 m. The above-mentioned authors look for the explanation of the phenomenon in the horizontal pressure to which the ice is subjected in this place. The circumstance that similar furrows and edges might be met with on the surface of the ice points in the same direction. The regular arrangement and the sharp edges exclude all possibility of the phenomenon being caused by melting water. The ice was

Fig. 5. Nearer view of the furrowed ice (J. P. Koch and Wegener).

distinctly stratified throughout the height of the wall, the lowermost 6 to 8 m containing ground moraine.

A peculiar marginal phenomenon, which seems to be of not infrequent occurrence in North Greenland, was described by Chamberlin from observations made on Red Cliff Peninsula. On a plateau the base of the local ice cap lies at a height of about 600 m. The edge is composed of a 30 m odd high snowy slope, crowned by a terminal moraine, on the other side of which rises the dome of the ice cap. The outer slope partly consists of pure white snow, partly of dirty older snow or ice; in a few places was seen stratified, granulated ice "of glacial aspect" and containing some rocky material. The phenomenon is due to the fact that the prevailing direction of the winds is down the slope of the ice cap, and they deposit so much snow at the base of the ice front that the snow can remain from one year to another. This wind-drift border was from 10 to 20 m, up to 1 km broad, and it was so steep that it was difficult to ascend it in a straight, but not in a slanting line.

As regards the aspect of the ice front mention should also be made of the relatively violently stirred sections, the glacier tongues or lobes, where these end on land. Chamberlin thinks that it is possible to distinguish between two types, a northerly and a southerly, the former characterized by the verticality of the face, the latter by the curved profile of the terminal slope. To the latter type belong not only the glaciers in the southern part of Greenland, but it is also the common type found in the Alps and wherever glaciers occur in lower latitudes; it is the form produced by the melting-off, which increases gradually towards the glacier end. But in

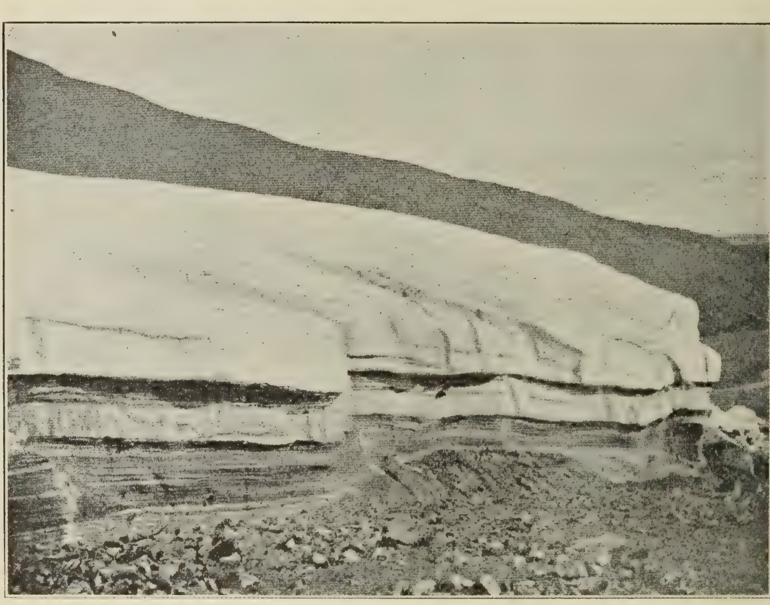

Fig. 6. Vertical face of Bryant Glacier, North Greenland (Chamberlin).

the regions north of Cape York, Chamberlin has described a series of glaciers which terminate in a steep wall, whereas the normal type with the sloping terminal plane is only said to occur exceptionally. Sometimes the face is not merely vertical, but it is disposed to overhang, so that from time to time the upper portion breaks away and falls to the base. This disposition to overhang is doubtless to be attributed, partly to the more rapid movement of the upper layers of ice, and partly to the more rapid melting of the discoloured ice below, the two forces acting jointly. The verticality is not only a characteristic feature of the end of the glacier, but of the sides. This seems less strange, for here we might find a plausible explanation in the undermining of the streams that run alongside the glacier and in the reflection and radiation of heat from the adjoining cliffs. But the vertical terminal face occurs, even where there is a level plain in front of it, and it is also independent of exposure. Chamberlin regards the phenomenon as an

effect of the latitude. It is obvious that the rays of low slant strike the back of the glacier at a very acute angle and easily glance away with little effect. On the edge of the glacier they strike more directly against the surface and hence have greater effect. In high latitudes where the sun is always low, a larger *proportion* of the sun's rays fall on the edges of a glacier than upon the edges of a glacier in low latitudes, and it is the *proportional* effect of the sun's rays that determines the contour [1]. This explanation, however, does not stand uncontradicted, as Salisbury, from observations on Ellesmere Land in lat. 78° N., arrives at the conclusion that the glaciers have the same general characteristics as those in South Greenland, and more particularly lack the vertical ends. On the other hand, he found that many of the glaciers on Baffin Land, between lat. 71° and 73° N., had vertical sides and ends, and thus the phenomenon cannot simply be an effect of high latitudes. "Whatever may prove to be their explanation, it seems to be true that thick glaciers of high gradients are much more likely to possess vertical sides and ends than thin glaciers of low gradients [2]."

The Cryoconite. During his first trip on the inland ice of Greenland in the year 1870 Nordenskiöld found that at a distance of only a few hundred metres from the ice front there was not a single stone on the surface of the ice, but instead of that there were everywhere vertical cylindrical holes of up to a metre in depth and from a few millimetres to more than a metre in diameter, and situated so close to each other that one would in vain look for a place to put one's foot, let alone one's sleeping bag. The holes were always filled with water, and at their bottom a layer of grey powder, several millimetres thick, was visible. This powder Nordenskiöld called cryoconite, which name surely contributed towards the fame acquired by it in the world of science. He regarded it as an atmospheric sediment of essentially [3] cosmic origin, and this view he based, in addition to its contents of iron, cobalt and nickel, on the fact that the cryoconite, according to his observations, occurred in equal amounts near the edge of the inland ice and 100 km farther in. Otherwise Nordenskiöld considered these cryoconite holes more dangerous than the yawning crevasses, for it was possible to walk around the latter, while it was almost impossible to avoid thrusting one's legs into the former. Also J. A. D. Jensen describes the holes as greatly hampering progress, and J. P. Koch says of Storströmmen that it was so filled with "midday holes" as to suggest a huge sponge; Kornerup, who accompanied Jensen on his trip, says that the ice mass everywhere, but particularly in the neighbourhood of the nunataqs, was imbued with a

[1] Journal of Geology, III, 1895, page 566.

[2] Salisbury, Journal of Geology, III, 1895, page 890.

[3] Later on, however, Nordenskiöld modifies his statement, stating that the cryoconite *partly* consists of cosmic dust (Studier och Forskninger, page 125 ff.).

dark grey or brownish clay dust, formed by the decomposition of the mountains and carried across the ice by the wind. Nansen found that in the interior of Greenland there was no cryoconite whatsoever and in the neighbourhood of the east coast very little, and this he ascribes to the fact that in the region in question there were only scattered nunataqs and no large continuous coast land from which dust might come. Near the west coast, however, he found cryoconite, although in small amounts, at several places up to a

Fig. 7. Cryoconite holes (Steenstrup).

distance of more than 30 km from the ice front. The view entertained by Jensen and Nansen is the one most commonly prevailing, though it should be mentioned that Harder has set forth a somewhat deviating opinion, *viz.* that what has been called cryoconite is in reality a decomposition product of excrements of ptarmigans. However, the analyses made, as for instance by Quervain, seem to prove with sufficient strength that the cryoconite is of terrestric mineral origin.

Drygalski has undertaken a series of measurings of the cryoconite holes by which it has been proved that, apart from the quite thin tubes, the number of which is legion and which he considered as incompletely developed tubes, by far the greater number have a width of 5 to 10 cm. A width exceeding 15 cm is rare in the case of individual tubes, but when several are

united, broader holes may form. Irrespective of the width a depth of 40 to 50 cm is the most common; then come in succession 50 to 60 cm, whereas greater depths are very rare, and lesser ones in the main are combined with the fine, undeveloped pores. The holes are formed by the dust absorbing the heat of the sun more readily than the ice and, therefore, gradually melting down into the latter, though only to a certain depth. The reason why the deepening stops at 50 to 60 cm must be that the rays of heat are absorbed by the water filling the holes, for if it was due to the fact that the wall overshaded the rays of the sun so that they could not reach the dust, the depth of the holes would have to increase with the width; this, however, is not the case. Therefore, Drygalski sees in the cryoconite a fixed horizon which in summer melts down more quickly than the surface, but in the autumn is overtaken by the latter: "So lange also ein bestimmter Staubhorizont existiert, ist die Overfläche in einem Zustand der Erniedrigung begriffen, weil sie dem Staubhorizont folgt [1]." In the non-existence of cryoconite holes on the east side and their presence on the west side of the inland ice he sees an indication that the supply of snow on the east side exceeds the melting, while the opposite is the case on the west side. Besides, he connects the dust horizon with the stratification, as will be mentioned later on.

As mentioned above, the holes are generally filled with water in summer. At Igdluluarssuit Glacier on Prudhoe Land Chamberlin made the observation that whenever thawing was checked by cold weather, it was quite promptly followed by the total disappearance of the water from the dust wells. It, therefore, appeared quite certain that the water melted upon the surface was absorbed with considerable rapidity into the glacier. At noon he sometimes saw that a film of ice stretched across the upper part of these wells, and that the water within them had shrunk away, two or three inches from the film. Occasionally there was a second film, two or three inches below the first, and from this also the water had sometimes shrunk away. The film of ice had frozen during the preceding night, and the falling away of the water beneath in the 10 to 12 hours that had elapsed since then was proof of the facility with which a glacier drinks up water on the surface. In contrast to this Drygalski tells that the water, when the surface is frozen, is subject to such a pressure that it wells forth when a stick is thrust against the ice cover, as a rule even bursting the first formed ice cover. In 1892 the freezing began on September 12th, and on the 17th the deepest holes were frozen to their bottoms.

Besides the vertical circular cryoconite holes Engell mentions some in Sarqardleq Glacier which are oblique, kidney-shaped and always orientated in such a manner that the concavity is towards the south, while their axis which points upwards to the south forms an angle of about 50°

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[1] Drygalski, 1897, page 103.

from the plumb line. Their diameter is generally about 1 dm; the smaller they are the more their cross section approaches the circular and their position the vertical. The oblique position must be explained by the fact that the dust which lies nearest the northern margin receives more of the rays of the sun and, therefore, melts down more quickly than at the southern margin, which is in the shade. The kidney shape must be due to the daily motion of the sun.

Crevasses. The glaciers issuing from the inland ice or from the local névés of Greenland are naturally, like other glaciers, traversed by crevasses which, according to their position and direction in relation to the movement of the ice, may be referred to the types so well known from the Alps and elsewhere, *viz.* marginal transversal and longitudinal crevasses. The marginal crevasses are due to tensions in the ice, called forth by the increase of the movement from the margin towards the middle of the glacier, and their direction is from the margin obliquely inwards and backwards. The transversal crevasses are formed where the movement for some reason or other—inequalities of the underground or the like—increases in the direction of motion; thus a strain develops in this direction and is relieved by the formation of crevasses. Finally, the longitudinal crevasses run parallel to the direction of motion, and may either be due to a strain at right angles to the latter, for instance, where a glacier has the opportunity of spreading to the sides, or to an abrupt transition from a slower to a more rapid movement, crosswise to the direction of motion, which in the following will be mentioned in detail.

A deviating classification is given by Drygalski who at Great Qarajaq distinguishes between three zones, *viz.* that of the marginal crevasses, of the simple crevasses and of the crossing crevasses. By marginal crevasses he understands crevasses, which circle the incisions made into the ice margin by the marginal lakes; their formation being due to a local movement outwards in the direction of the margin, they must rather be regarded as local transversal crevasses. The "simple" crevasses are generally due to an unequal rate of motion and are by Drygalski parallelized with the marginal crevasses mentioned in works on the Alps [1], but in reality they also comprise the transversal as well as some of the longitudinal crevasses. According to Drygalski the occurrence of frosts plays an essential part in the release of the state of tension produced by the unequal rate of motion, while the running water is an essential factor in developing the narrow fissures into actual crevasses.

On the inland ice itself crevasses are also met with, but only in the marginal zone which, it is true, is very unequal in breadth. Thus on the east side Nansen only met crevasses up to a distance of 15 km from the coast,

[1] Heim, Handbuch der Gletscherkunde, page 205.

whereas on the west side he found the innermost crevasses 40 to 50 km from the margin. There were here few crevasses and these almost exclusively transversal. Outwards in the direction of the margin the number increased rapidly, and besides the transversal crevasses which were still of most frequent occurrence there were also longitudinal crevasses. Particularly large were the crevasses in the neighbourhood of Kangersuneq Fiord.

Whereas Nordenskiöld on his trip across the ice in lat. 68½° N. only found crevasses in the immediate vicinity of the margin, Quervain in 1912 found crevasses 145 km from the ice margin, and very large crevasses at a distance of 125 km, the latter in the exact continuation of Jacobshavn Glacier. Also on his shorter trip across the ice in 1909 Quervain encountered crevasses—transversal crevasses—up to a distance of about 100 km from the margin; in the outermost 30—40 km the directions of crevasses were

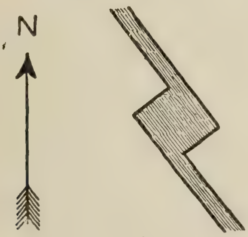


Fig. 8.

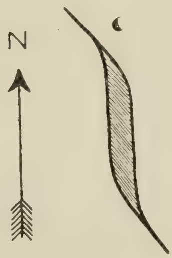


Fig. 9.

in pronounced harmony with the two fiord systems, Sermilik and Itivdliarssuk, the main direction of which was north-west to south-east, and Qarajaq with the main direction south-west to north-east.

It has been mentioned above that longitudinal crevasses may be formed as fault planes between portions of glaciers with a varying rate of motion. Interesting observations to this effect were made by J. P. Koch when in 1912—1913 he wintered on the glacier Storströmmen in Northeast Greenland. The extreme outer portion of the glacier moves very nearly in a direction north-west—south-east, and the southwestern portion, which is the one examined more in detail, is divided lengthwise into several belts of varying height, rising from south-west to north-east, or from the side towards the middle of the glacier. The transition between the various zones is formed of systems of longitudinal crevasses. In the course of the winter a creaking in the glacier was frequently heard, sometimes accompanied by pushing, but the cover of snow concealed the newly formed narrow fissures. Only gradually, as the crevasses became broader, and the cover of snow burst, a more detailed investigation became possible. In many cases it then appeared that the north-easterly wall of the crevasse had become displaced towards the south-east in relation to the southwesterly wall. As the crevasse was not right-lined throughout, its width

owing to the displacement, became rather varying, as illustrated by fig. 8. In this manner lens-shaped "cauldrons" had formed at greater bends in old crevasses, most frequently with vertical walls (fig. 9). Their dimensions might be very considerable; one particularly large cauldron was about 500 m in length, 200 m in width and about 44 m in depth. These cauldrons continue their existence and growth through periods extending over a number of years, but owing to the melting-off the walls gradually become less steep, so that they rather appear as elongated, deep depressions. Besides the longitudinal crevasses there were transversal crevasses along

Fig. 10. Small melting hummocks on Storströmmen (J. P. Koch and Wegener).

a distance of up to 1 km from the glacier front and parallel to it. In several of these differences were observed in the levels of the margins; these differences might amount to as much as a couple of decimetres, the margin nearest to the glacier front always being the lowest.

Melting Hummocks. The crevasses are not the only obstacles which meet the wanderer in the marginal zone of the inland ice. Also between the crevasses the surface of the ice is frequently very uneven, being partly furrowed by river beds, and partly strewn with irregular melting hummocks, which are so close together that one must constantly turn aside and proceed along a greatly curving line. There is, however, in this respect a great difference between the various parts of the inland ice. Thus Jensen mentions "steep ice hummocks of up to 10 ft. high, which made progress very difficult," whereas Garde says that only in quite few places where projecting headlands stopped the ice, were closely packed masses encountered, the

tops of which might attain a height of 3—4 ft. It will appear that Garde speaks of closely packed masses, but he expressly refers to Jensen's description, which undoubtedly applies to "melting hummocks." These are also mentioned by J. P. Koch and Wegener from their journey across Storströmmen, where they increased in height from east to west, *viz.* from some ½ m to 3—4 m. These authors look upon the melting hummocks as an ex-

Fig. 11. Rivulet on the surface of the Gnipa Cave Glacier (J. P. Koch and Wegener).

pression of a state of equilibrium between the melting-off by solar radiation and the melting-off by warm air, the rays of the sun being readily absorbed by water, but reflected by dry ice so that their power is greatest in the already existing depressions where the melting water gathers, or, in other words, they have an intensifying effect on the inequalities of the surface. On the other hand, the warm air naturally acts most strongly on the elevations, thus striving to smooth the inequalities. Like the authors mentioned above, Ejnar Mikkelsen describes the surface of the inland ice as very hummocky over long distances, whereas Quervain does not seem to have been much troubled by inequalities.

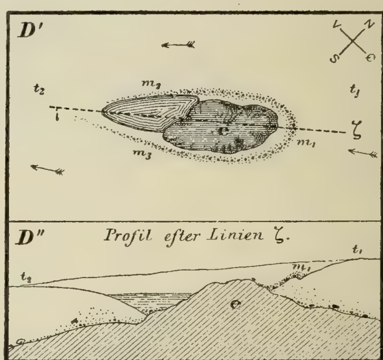
Further, as to the *water courses* the expeditions on the inland ice have encountered surprisingly different conditions. Whereas both Nordenskiöld and Jensen were greatly impeded by the numerous rivulets which during the summer cut up the surface of the ice to a height of 1500 m, Nansen, on the west side, only met with rivulets and frozen-up lakelets up to a height of about 1300 m, and those even in small quantities, while on the east side he merely saw a couple of insignificant rivers a few km from the coast, and 800 m above sea level. The greater rivers frequently flow in deep channels with steep walls and are, therefore, difficult to pass, even when they are frozen up. But their course is generally short, and so Nordenskiöld's advice is, whenever the route is crossed by a river, to follow its course downwards, as it will then soon be seen to disappear in a crevasse or a bottomless hole in the ice. In a few places, however, the opposite has been observed, a powerful water course welling forth like a fountain from a hole in the ice. The direction of the water-courses is frequently determined by the crevasses or by the so-called ribbon structure, which will be mentioned in a subsequent chapter.

Kornerup del.

Fig. 12.

In the snow-drift glaciers on Germania Land J. P. Koch and Wegener frequently observed rivulets of melting water the meanders of which were extremely regular (fig. 11). The current in these rivulets was always very rapid.

Moraines. It is noteworthy that moraine material is extremely rare on the surface of the inland ice. Thus, Nordenskiöld says that a few hundred metres from the margin even a stone of the size of a pin head is looked for in vain. At the margin of the ice, and particularly at the margin of the glacier, a more or less thick ground moraine is melting out, and on the surface of the glaciers medial moraines are occasionally seen issuing from nunataqs, and lateral moraines of the same nature as the corresponding formations on glaciers in lower latitudes, but on the inland ice proper moraines are a rare sight.



Th. Bergh's lith. Inst.

Fig. 13.

From the Jensen as well as the Dalager Nunataqs within Frederikshaab Iceblink, Kornerup describes peculiar moraines which, like horseshoe arcs, connect the nunataqs. In one place a nunataq, whose surface was lower than the surrounding ice, was almost entirely enclosed by a moraine wall, which on the north-easterly side was higher than the summit of the nunataq. The rocks occurring in the moraines were partly different from those found on the nunataqs.

By way of explanation of these horseshoe moraines Suess[1] calls attention to observations made during the building of some dikes in the Danube. By an accident the water burst open the dike, and where it rushed through a 16 m broad aperture, it exercised, in the first place, a very powerful erosion in the substratum so that, in one case, an oblong hole, about 20 m deep, was formed; then when the water had got through the opening, the lines of the current spread, as it were fan-wise, and as at the same time the rate decreased greatly, the water had to deposit the coarsest of the material stirred up from the bottom, the deposition taking place at a spot at right angles to the lines of the current, *viz.* in a wall shaped like an arc or horseshoe. In a similar manner Suess imagines the horseshoe moraines to have been formed through the compression of the ice between the nunataqs. Quite apart from the fact that it seems doubtful whether any noticeable compression takes place, as the ice has unlimited access to deflect to the sides, while the waters of the Danube could only use the accidentally formed passage, there is the marked difference that the carrying capacity of the ice by no means decreases with its rapidity, and therefore the ice is not under the same necessity as the water to deposit its contents of debris below the narrowing.

Kornerup is undoubtedly right when he looks upon these moraines as portions of the ground moraine which is forced to the surface by the movement of the ice across the undoubtedly elevated ground between the nunataqs, as illustrated by his section (fig. 12). Fig. 12 B'' shows how the ice, which passes between the nunataqs (t_3) along part of the distance, pushes over the more slowly moving ice lying in front of it (t_5). This supposition of Kornerup's harmonizes, as it will appear later on, very well with the ideas of the mechanics of the motion of the ice, which we must form on the strength of other observations.

Similar horseshoe moraines are mentioned from the Holsteinsborg District by Jensen and from the east coast by J. P. Koch and Wegener.

From several localities mention is made of the phenomenon of the base of the ice margin consisting of a rather steep ice slope which is crowned by a moraine, behind which the ice rises more gradually. Quervain describes the phenomena at the margin of the inland ice itself (fig. 14): the steepness of the outer slope was here, at Nunap Kigdlinga, about 35°, its

[1] La Face de la Terre, II, page 572.

height about 50 m. Exactly the same relation Chamberlin demonstrated at the ice cap on Redcliff Peninsula, where the edge consisted of a steep snowy slope, about 30 m high, so steep in fact that it was difficult to climb it in a straight line, whereas it could be done with some caution in an oblique one. At the top of this slope lay a terminal moraine, beyond which the ice dome rose. In these and other cases where conditions have been made subject to closer investigations, it has, however, proved that the outer slope consists partly of pure, new snow, partly of dirty, older snow and relatively fine-grained ice, and it is therefore regarded as a secondary formation, an accumulation of snow due to the winds from the interior of the area, which

Fig. 14. Margin of the inland ice at Nunap Kigdlinga (Quervain).

are the prevailing ones. Quervain is of the opinion that this accumulation, when once formed, makes such resistance against the pressure of the ice as to produce the upward curvature of the layers which was distinctly observed in a profile through the moraine; the latter would thus actually come to be deposited on top of the snow slope. Also Chamberlin found that the layers of ice curved rapidly upwards on encountering the wind-drift border and the moraine lodged against it, but the actual snow-drift showed no trace of a pressure. Thus, the problem still remains unsolved whether the snow-drift is not simply resting on the outer slope of the moraine instead of being lodged below it.

The ground moraine will be mentioned in connection with stratification.

STRUCTURE.

Glacier Granules. Like all glacier ice the inland ice also consists of closely connected ice granules of varying size, the projections on the irregular surfaces of the granules interlocking. Every granule is a crystal individual. In mountain glaciers one generally sees the average size of the granules

increasing in the direction from the névé to the end of the glacier, even though there is everywhere in the glacier an intermixture of large and small granules. Thus, the size of the granules, to a certain extent, seems to be a function of the distance traversed by the ice, and therefore one might expect to meet with particularly large granules in the marginal zone of the inland ice where ice masses are seen, the routes of which many times exceed the length even of the largest mountain glaciers. This is, however, in no wise the case. Drygalski regards granules of the size of a small pear as the exception, the maximum size as a rule being like a large walnut. Quervain estimated a particularly large granule at about 150 cm^3, and another of 80 cm^3 still seems to have been an exception. Moltke and Jensen mention glacier granules varying from the size of a hazelnut to that of a hen's egg, dimensions which are quite commonly attained or even surpassed by the granules of the Alpine glaciers. As the growth of granules is supposed to be connected with interchanging meltings and regelations in the interior of the glacier, it must be concluded that the arctic glaciers and the inland ice itself, in this respect, offer poorer conditions than the glaciers of the temperate zone, so much poorer as not to be counterbalanced by the longer distance which the ice has to pass in Greenland.

As to the arrangement of the granules, it is, according to most observers, quite irregular. However, on Storströmmen J. P. Koch found that the granules were generally embedded in a cement of quite small crystals or crystal fragments, arranged concentrically round a centre or a common axis. Such a group of "arranged" crystals might have a volume of about 1 dm^3. Also the orientation of the optic axis of the crystals is generally quite irregular, but in the lower portions of the ice, particularly where the latter were distinctly stratified, Drygalski demonstrated that the axes were very frequently at right angles to the layers, even though there were also many exceptions here.

Air Bubbles. As is well known, the glacier ice is generally filled with an immense quantity of small air bubbles or pores. Steenstrup observed that the pores were rounded at a temperature of 0°, whereas at temperatures below 0° they were flat and more angular, and that the air enclosed was subject to a strong compression, so that even a pressure with a needle might be sufficient to burst a large piece of ice with the crack of an explosion. It is also a commonly occurring phenomenon that an iceberg suddenly crumbles into innumerable fragments, and this naturally has some bearing upon the fact that the glacier ice is charged with explosive matter.

Even Saabye mentions that when the top of an iceberg is "rotten," one may run the risk that it topples down if a shot is fired or even a voice raised in the neighbourhood, for which reason the Eskimos always keep perfectly quiet, when they are obliged to pass an iceberg at close quarters.

Steenstrup looked upon the phenomenon as a simple consequence of the contraction of the ice at the lower temperature, while J. P. Koch at Storströmmen made the observation that the air in the pores was subject to a pressure of about ten atmospheres, and such a great pressure cannot be produced by the mere diminishing of volume by cooling. J. P. Koch draws attention to the fact that at a certain depth of the névé one must arrive at a layer which is so dense as not to permit the air to pass through it, and the pressure of the superincumbent layer must then lead to the compression of the confined air.

Ribbon Structure and Stratification. In the land ice of Greenland three kinds of lamination can be observed. In the central regions the interchange between periods of precipitation and periods of non-precipitation produce an accumulation of superimposed layers of snow, or, in other words, a real stratification; within the lower parts of the accumulation area, where the upper layers of snow melt in summer, interchanging layers of ice and snow are formed. At the margin of the inland ice, and not least at the margins of the Greenland glaciers, a succession of layers or laminæ is observed, consisting of the three components of the glacier mass: ice, air-bubbles and rock débris. Finally, there are, also in the marginal zone, lamellæ or ribbons of compact, transparent ice, embedded in porous, opaque ice. That these three structural forms are sometimes connected with each other is as certain as that, at other times, they appear quite independent of each other, but the nature of their mutual relation is a complicated problem, of which the investigations hitherto made only yield a partial solution.

In Greenland investigations of the original lamination of névés were especially undertaken by J. P. Koch during his passage across the inland ice in 1913, where at each camping place a horse stable was excavated 2 m in depth. On Bergjökul on the east coast, at a height of 600 m, *viz.* within the ablation area, only porous ice was seen, without any trace of stratification. At a height of 1600 m there was half a metre of snow on top; then followed a couple of centimetres of ice and then again interchanging layers of névé snow, a couple of decimetres thick, and ice of a couple of centimetres, down to the bottom of the stable. The ice was formed by the summer melting of snow, and thus a layer of ice plus a layer of snow corresponded to one year's accumulation. Corresponding conditions were encountered at a height of 1900 m, but above 2100 m ice was no longer met with in the course of the digging; thus, in by far the greater part of the interior of Greenland no melting of the snow takes place. The lamination of the snow is very fine. In the upper metre and a half J. P. Koch thus counted about fifty layers, and at a depth of three metres and a half the layers could no longer be distinguished. At a depth of 6 m the snow began to assume an ice-like character, but it was still so porous that no resistance was felt, when placing

the mouth against the wall of the shaft and blowing into it. Therefore, circulation of air may probably take place in the névé at a rather considerable depth, and it will further the sublimation process by which in these regions snow must be transformed into ice.

Also Quervain, on his voyage from coast to coast in 1912, undertook regular borings, but as a rule only to a depth of about one metre. Above 2400 m only snow was found, which became more compact downwards, and his results correspond with those of J. P. Koch. At a lesser height interchanging layers of ice and snow were encountered, representing a yearly precipation of about 35 cm of water, to which, however, must be added the waste through evaporation which, by Quervain, was computed at about 5,5 cm.

As already mentioned, the stratification of the névé in the deepest excavations undertaken by J. P. Koch was not to be distinguished at greater depths than 3 to 4 m. But down to the greatest depth reached, *viz.* 7 m, the blocks of snow, when being dug out, showed a tendency to crumble into flakes corresponding with a horizontal stratification. From this fact to draw the inference that the inland ice is stratified right down to the bottom, is naturally not justifiable. At the terminal wall of Storströmmen which rose 30 m above the sea, there was no visible stratification corresponding to that of the névé, but other circumstances, for instance, the greater or lesser ease with which the glacier ice splits in various directions, seems to indicate that such a stratification nevertheless existed.

As to the ribbon structure it will be expedient to begin by separating a form of the latter, which has decidely no connection with the stratification, but, on the other hand, has some bearing upon the crevasses. Drygalski uses the term "Querbänderung," because the ribbons in question run crosswise to the longitudinal direction of the motion of the glacier tongue. They arise when the crevasses are filled with water, which in freezing forms compact ice. However, this generally does not happen in such a way that the fissures are simply filled with water to their very edges, the connection with the deeper lying cavities in the ice normally being far too free for that. But water oozing down the walls of fissures may freeze to compact ice, and if then, owing to pressure, the crevasse closes, a ribbon appears on the glacier surface, consisting of clear, compact ice, with a lustreless plane in the centre. When purest, the ribbons are blue in comparison with the porous white ice which otherwise composes the glacier, but they are frequently brown, grey or greenish with dust blown into the fissure or washed down there by the melting water. The ribbons formed in this manner, which, by their direction as well as by the lustreless plane in the middle, are easily distinguished from the above-mentioned blue ribbons proper, are generally only a few centimetres broad.

Clear, compact ice can, however, as pointed out by J. P. Koch [1], also be imagined to have been deposited by sublimation on the wall of a fissure. On the under side of a layer of snow which covered a crevasse in Storströmmen, he found well developed, large ice crystals. If a crevasse either does not reach the surface of the ice or is closed at its upper edge by a layer of snow, so that wind and fluctuations of temperature do not make themselves felt, a very faint circulation of air will arise in the crevasse, owing to the slow, gradual increase of temperature with the depth. The relatively warm vapour-saturated air from the lower lying part of the crevasse will rise, be cooled, and precipitate white frost in the more elevated portions of the crevasse. When for some reason or other the crevasse closes after a rather long time, a blue ribbon will have formed with a seam in the middle. In the northern part of Storströmmen the walls of the snow-covered crevasses, in May 1908, were frequently clothed with a thick layer of white frost, which made it impossible to investigate the structure of the ice [2].

Salisbury also describes transverse veins, consisting of compact blue ice near their front and back walls, while the central portion was notably more granular.

From of old a structural phenomenon is known from the Alpine glaciers under the name of blue ribbons, as to the origin of which opinions vary greatly. The blue ribbons form spoon- or cup-shaped planes with the concave side upwards, standing out against the surface as blue ribbons which partly pass in the longitudinal direction of the glacier and partly—in its lower section—form downwards convex arcs across the glacier. From Great Qarajaq Glacier and the adjoining parts of the inland ice Drygalski describes the ribbons, now as quite fine stripes, which by their dark-blue colour are distinguished from the surrounding porous ice, but can only be traced over a short distance and then thin out and disappear, now as ribbons 10 cm or more in breadth, which can be traced over longer distances. As a rule there is a fairly large number of ribbons side by side, sometimes as many as twenty a metre in width. They run, in the main, parallel with the margin of the ice, that is, on Qarajaq Glacier in the direction of motion, on the inland ice at right angles to the latter, and this very fact Drygalski regards as evidence of the identity of this structure with the blue ribbon structure of Alpine glaciers, which at the end of the glacier passes athwart it. To be used in his observations of the motion of the ice Drygalski marked off with stakes a considerable number of points in the ice, and thus he was able to prove that the blue ribbons within the period between September—October, 1892, and June—July, 1893 had changed, both as regards form and position. In some cases ribbons which had been found on the first observation had disappeared on the second; in other cases new ribbons had

[1] J. P. Koch, 1915, page 346.

[2] J. P. Koch and A. Wegener, M. o. G. XLVI, 1, page 35.

formed in the meantime, or quite narrow ribbons had grown into wide ones. The ribbon structure has presumably some bearing upon that which Salisbury describes as a vertical arrangement of layers, and which, according to him, appears to belong to the category of veining rather than stratification. In Northwest Greenland these vertical veins appeared to be altogether absent in many glaciers, and to be present in portions only of many others. Where present they sometimes showed themselves on the surface of the ice, so that when crossing the glacier, lining parallel to its axis was conspicuous. The vertical—longitudinal veins were of varying thickness, but usually less than an inch. Vertical veins transverse to the axis of the glacier were seen in several places. "They affect some glaciers where the longitudinal set is wanting, and some where it is present. The two sets of vertical veins may be in different portions of the same glacier, or they may affect the same part [1]."

It will appear that Salisbury distinguishes between two structures, veining and stratification, but without entering in detail into the relation between them. Also other investigators regard stratification as a structure different from the ribbon structure, although the two structural forms sometimes pass into each other. On the other hand, judging by his mention of Qaqortoq Glacier, Chamberlin seems to consider the two structures identical when he writes: "In crossing the wide expanse of the foot of the Qaqortoq Glacier it was observed that the blue layers—which best indicate the stratification of the ice where debris is absent—were continually coming to the surface by an upward curvature, which increased as the surface was approached— — —It seemed very manifest that, at least in this glacier, the blue and white bands which appear as stratification in the vertical faces, assume the form of highly inclined folia on the glacier's surface, closely analogous, if not identical with the much discussed "ribbon structure" of Alpine glaciers [2]."

It is only in the lower layers of the ice that stratification becomes at all visible. It must, however, be emphasized at once that from the description of this structure, given by those who have had the opportunity of investigating it in Greenland, as well as from the views of its origin based on these investigations, it is in the highest degree doubtful whether it is really a case of stratification in the sense in which this word is used in geology. One is rather tempted to use the term schistosity which, however, would hardly be acknowledged by all investigators. A more neutral term is lamination, which is, for instance, used by Chamberlin and Salisbury [3]. When at a later period the same authors use the term foliation [4], this is

[1] Journal of Geology, IV, 1896, page 786.
[2] Journal of Geology, III, 1895, page 835.
[3] Articles in Journal of Geology, 1894—97.
[4] Chamberlin and Salisbury, Geology.

not quite so appropriate, as some investigators of Alpine phenomena use it about the ribbon structure[1], which is only in part identical with what the American authors understand by foliation.

First of all we will glance at the descriptions given of this structure.

According to Drygalski the stratification ("Schichtung") partly consists in a definite arrangement of layers of sand and débris, partly in an arrangement of the air bubbles. It is not that continuous layers of débris or air divide layers of ice, but certain layers are particularly rich in small and thin parallel accumulations of sand or air; they belong to parallel planes, but not to the same plane. As some streaks end where others begin, closely above or below them, the impression created by the whole occurrence is sometimes rather that of lamination ("Flaserung") than of stratification. The stratification is generally parallel with the underground, but in details there are many deviations. Where a stone is embedded in the ice, the layers curve about it. In a downward direction the stratification often gradually passes into the ground moraine.

Salisbury's description of the stratification, which is based upon observations from the regions north of Cape York, only supply a few new details. It is interesting that he gives prominence to the fact that certain layers of the ice are more solid and blue, and certain other layers more porous and white. The presence of débris between the layers often helps to emphasize their distinctness, but their existence is not the result of the presence of débris. It is upon the varying texture of the different layers that the stratification in the upper part of a glacier is usually dependent, while the débris often emphasizes the distinctness of the layers in the lower portion.

The stratification was the main object of the researches made by Chamberlin in Northwest Greenland, and to him we are indebted for much detailed information. About the stratification in Fan Glacier on Red Cliff Peninsula, he says that it partly consisted of alternations of relatively thick, porous, opaque white layers, with thin, solid translucent blue ones, partly in an embedment of rock rubbish between layers of relatively pure ice. It was interesting to observe that the laminæ parted, as they approached a boulder, a portion curving over the boulder and a portion curving under it[2]. In Bryant Glacier the ice is not only arranged in layers, but these are subdivided in a very intimate fashion, so intimate in many portions as to pass beyond simple stratification in its usual sense and become lamination. Where the ice was closely laminated, the larger boulders necessarily extended across the horizon of several laminæ, and in many of these cases the laminæ divided, a part bending up and passing over the rock fragment and a part bending down and passing under it. In cases where the mass was larger, some of the central laminations ended abruptly against the mass,

[1] "Blätterung" (Crammer).

[2] Journal of Geology, III, 1895, page 476.

and new laminations appeared on the opposite side, while the laminæ above and below were bent around the mass. The laminations that bear the débris are not usually continuous for great distances. The layers thin out and disappear, and others are introduced to take their places; even the broader bands are limited in their extent.

At the eastern margin of Storströmmen J. P. Koch, in 1912, found a well developed system of blue ribbons, running parallel with the glacier front. They were somewhat embedded as they are more apt to absorb the rays of the sun than the white porous ice [1]. The ribbons were fissured parallel with the margins. They thinned out, forming not continuous planes, but rather thin blue ice foliæ, which entered like elements into a cup-shaped stratification in the glacier. The ribbon system merged quite gradually into the stratification of the lateral wall of the glacier; they were here less steep—bending towards the glacier—than on the surface of the glacier.

In the southern part of Storströmmen blue ribbons particularly appeared in the formerly mentioned crevasse zones, which passed in the longitudinal direction of the glacier, and which turned out to be fault zones. In one of these J. P. Koch followed a 1.5 m broad blue ribbon over a distance of a kilometre. Towards the west it terminated in one of the "cauldrons" mentioned in the chapter on crevasses, towards the east in another blue ribbon passing at right angles to it 800 m from the glacier front. In another zone several vertical ribbons of 0.1 to 1.5 m in breadth appeared in the terminal wall of the glacier, consisting of compact ice with a brown tinge from moraine mud. The ribbons were traversed by vertical fracture planes, like the external surfaces of the former covered by a dust-like layer of mud; also a few small pebbles were seen, and this excludes the possibility of the ribbon being formed by the freezing of water which had filled a yawning crevasse. J. P. Koch looks upon the ribbons and the longitudinal crevasses as a manifestation of the same thing, *viz.* displacements in the glacier along fault planes. When once the crevasse is filled with compact, blue ice it is, however, not reasonable to suppose that future displacements take place in it; they rather take place along the plane dividing the blue ribbon and the porous ice, and if the new fissure is filled with blue ice the consequence is that the blue ribbons increase in thickness in the direction of motion, and this J. P. Koch finds confirmed by the South Icelandic glaciers.

[1] In the Alps it is, on the contrary, the blue ribbons which form the raised edges, and the porous ice which lies in the depressions. Heating by conduction from the air there plays a greater part than insolation, and therefore the compact portions, where the ice mass per unity of volume is greatest, is less affected than the portions largely consisting of air. The "Danmark" Expedition, also in Storströmmen, investigated a system of ridges of compact ice running parallel with the lateral margin of the glacier. "Diese Kämme sind anscheinend identisch mit den "Ogiven" der Alpengletscher und stellen die Blaubänderstruktur dar. Die Erhebung der Kämme über ihre Umgebung betrug selten mehr als ½ m" (Koch und Wegener, page 24).

It has been mentioned above that there was a distinct stratification in the eastern lateral wall of Storströmmen which passed into the surface ribbon structure. The "Danmark" Expedition observed an equally well developed stratification higher up in the same glacier, right up to Ymer's Nunataq, which is situated close to the névé limit, so close in fact that, according to J. P. Koch, the stratification may with good reason be supposed to derive from there [1]. But this stratification also comprises the ground moraine in the lower 6 to 8 m of the ice: "Sie streckt sich zwar als zusammenhängende Eis- und Schmutzschicht die ganze Wand entlang; aber die Schmutzschichten gliedern sich in eine grosse Zahl, oft kaum 1 cm

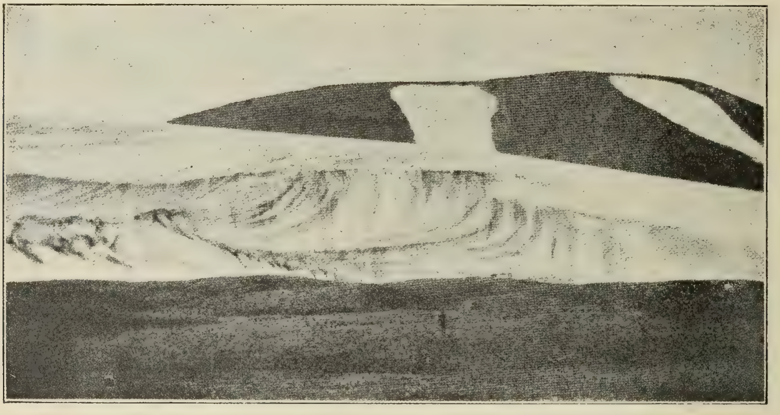


Fig. 15. Upturning of the layers at the end of a glacier. Olrik Bay, North Greenland (Salisbury).

dicker Horizonte, die zwar parallel sind, aber doch haüfig auskeilen und über einander greifen [2]." It can at any rate not be the original névé stratification, nor is it possible to decide whether the stratification of the pure ice above it is so. Even though the original névé stratification enters as an element into the lamination which appears at Ymer's Nunataq, a different stratification determined by another cause must already exist here. As, however, it is intimately connected with the mechanics of motion, it will be mentioned in the chapter on the motion of the ice.

As to the foliation of the ice special mention should still be made of the very common upturning of the layers at the ends and sides of glaciers, as well as at the edge of the inland ice or of local ice caps. In glaciers the upturning is generally most conspicuous at the extreme end. It becomes less and less striking with the increasing distance from the end and is not apparent at any considerable distance above. The upturning varies from a few degrees to verticality (fig. 15). Sometimes the upturning is associated

[1] J. P. Koch, 1915, page 355.
[2] J. P. Koch and A. Wegener, page 397.

with a notable thickening of the layers towards their edges. This suggests that perhaps there is an exceptional growth of the granular crystals of the ice near the edge of the layers, owing to the penetration of the surface waters [1].

The causes of the origin of foliation, in the widest sense of the word, most investigators find in the motion of the ice, and the various views of this problem will be discussed later on. Only in this connection should be noted the view held by Drygalski, *viz.* that the accumulation of brownish dust in a rather distinct layer, as caused by the so-called cryoconite holes, may also generate a stratification of the ice. As formerly mentioned a "cryoconite period" is, according to Drygalski, a period of decay for a given area of the inland ice. If such a period is now followed by another where the yearly supply of snow exceeds the melting-off, the cryoconite horizon is covered by a more or less dustless ice, which in its turn is covered by a new cryoconite horizon when the melting-off again takes the upper hand. In this manner interchanging white and brown layers might form. At the margin of the inland ice proper, west of Sermilik Glacier in South Greenland (about lat. 61° N.), Moltke and Jessen found that the ice was distinctly stratified with undulating dark streaks of clayey ice, and, like Drygalski, they associated this stratification with the dust covering of the surface [2].

Finally, mention should be made of the interesting, but rather isolated observation on the part of Drygalski as to the occasional occurrence in the horizontal stratification of a uniform orientation of the optic axes of ice crystals, *viz.* that they are at right angles with the stratification. As will be shown later on, this phenomenon is of importance to the view entertained by Drygalski as to the causes of the stratification.

Temperature of the Ice. Fairly comprehensive systematic measurings of the temperature of the ice have, in Greenland, only been undertaken by Drygalski and J. P. Koch. At Great Qarajaq Glacier the former, during the months November—July, determined the temperature at bore holes of up to 2.2 m in depth and also in crevasses at depths of 5.4 m and 8.9 m; the value of the measurings undertaken in the crevasses is, however, limited by the fact that the possibility of air circulation was not excluded. At a depth of 2.2 m the temperature on October 30th was —0.3°. The lowest temperature —9° was reached on March 27th, or almost two months after the surface temperature had attained its minimum; then the temperature again rose, till zero was reached on June 27th. As it will appear, the date of the lowest temperature is five months from the beginning, but only three months from the end of the cold period, which has some bearing upon the fact that air temperatures below 0° are only transmitted through the ice

[2] Chamberlin and Salisbury, Geology I, 1904, page 297.

[1] Medd. o. G. XVI, page 102.

by conduction, whereas the positive temperatures also act through the melting water which oozes down through the ice. Drygalski is of the opinion that the yearly variations will cease at a depth of about 30 m; that below this there is a rather thin layer with a negative temperature, and that the greater part of the 500 to 600 m thick glacier is always on the melting point. This, in his opinion, cannot be due to radiation of heat from the earth, as the yearly mean temperature in this place is —4°,6 at sea level, and in Drygalski's opinion would be still lower in a surface covered with a thick layer of ice, if the ice mass were stationary [1]. Still, again according to Drygalski, the movement and the associated stratification cause the temperature to rise to the melting point [2] within the lower part of the inland ice, which problem, however, we will return to in the chapter on the motion of the ice.

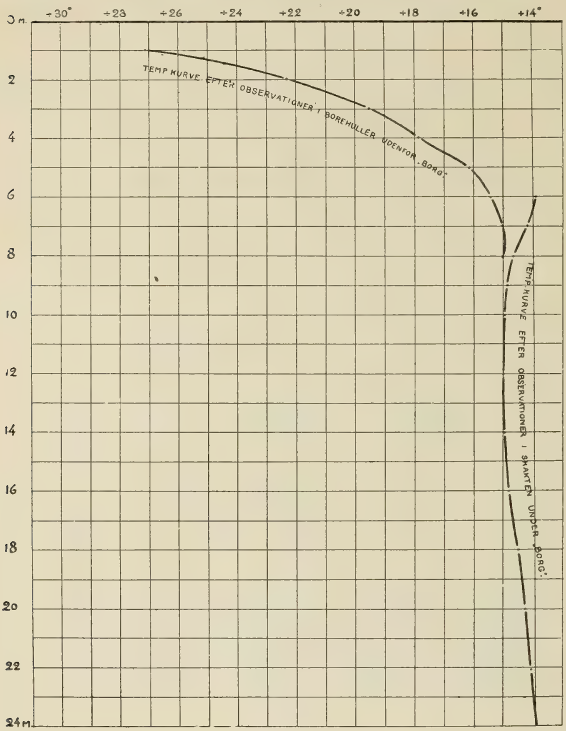


Fig. 16 (J. P. Koch).

J. P. Koch spent the winter 1912—13 at the large East Greenland glacier, Storströmmen, in lat. 76° 42′. The annual mean temperature is here about —17°. Measurings were undertaken at bore holes of up to 24 m in depth. Fig. 16 shows the curve of temperature for January 8th, 1913. It falls into two sections, because the bore holes partly lay outside, partly—the deepest—below the house of the expedition; the difference between the curves at depths of 6 to 8 m is due to the influence of the house. It appears how the temperature in the upper 7 m rises quickly to about —17° and then very slowly. The rise below a depth of 24 m seems

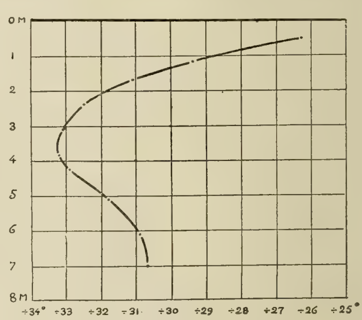


Fig. 17 (J. P. Koch).

[1] Verhandlungen des VIII Deutschen Geographentages zu Berlin, 1889, page 162.

[2] Grönlandexpedition, vol. I, p. 473.

to be nearly 1° in 20 m. As the thickness of Storstrømmen in the southern part is presumably about 250 m, this means that the whole of the ice mass has a temperature below the melting point. The variations of temperature naturally decrease with the depth, the ice in this respect being exactly like any other kind of rock. The yearly amplitude at the surface is estimated by J. P. Koch at 40° approximately, at a depth of 6 m at 5° approximately, and at a depth of 24 m, at some tenths of a degree.

Also in Central Greenland J. P. Koch undertook measurings of temperature in the ice down to a depth of 8 m. Fig. 17 shows the temperature curve for June 12th, 1913, measured at a height of about 3000 m. The curve seems to indicate that the annual mean temperature is here about —32°. The final working out of the temperature observations from the expedition of J. P. Koch has not as yet been undertaken.

MOTION OF THE ICE.

Mechanics of Motion. The many theories set forth in the course of time as to the movement of glaciers may be referred to two fundamental views. According to the one, the movement of the ice chiefly depends upon the plasticity which ice possesses, especially when its temperature is near the melting point, or on an interchange of melting and regelation of smaller portions of the ice. The movement is thus regarded as a kind of floating, the individual molecules being displaced in relation to each other. The other group of theories, however, consider the glacier movement as the result of displacements of larger, solid portions of the ice, whether glacier granules, foliæ, strata or still larger unities.

Both methods of explanation have been used in relation to the Greenland glaciers and the Greenland inland ice. At this point, however, it should be borne in mind that our knowledge of the motion of the inland ice itself is extremely slight, as the more detailed researches have, almost exclusively, been undertaken at the glacier tongues of the marginal zone, and it is quite uncertain to what an extent it is justifiable to conclude anything from this as to the movement of the inland ice.

In the marginal zone of the inland ice at Great Qarajaq Drygalski undertook a number of careful measurings of the movement of the ice. They extended over a period of nine months, and he proved by their means the existence of a vertical as well as a horizontal movement. The former, which he considered the primary, is, nearest the land, an upward movement decreasing with the distance from the shore, until beyond the 500 m distance it is replaced by a downward movement. Thus it can also be said that the upward movement is characteristic of the thinner portion of the ice, the downward movement of the thicker. Furthermore, the same author in the Agssakâq Glacier on the north side of Nûgssuaq Peninsula proved a

subsidence in the lowermost layer; a mark in the lateral wall of the glacier at a height of 1.2 m above the bottom was a year later 0.7 m above the bottom. This Drygalski regards as a proof of shrinkage in the lower layers of the glacier and only, or quite preponderatingly, within these, as the marks on the surface of the glacier, 80 to 90 m higher up, had only subsided about 3 m within the same period. Also, the stratification being closest within the lower layers a causative relation between the two phenomena seems pretty evident.

As has formerly been mentioned, Drygalski supposes that the greater part of the ice mass has a temperature very close to the melting point. If now the temperature increases ever so little, a small portion of the ice will melt, and indeed most and first in the lowest layers, because there the pressure is greatest and the melting point consequently lowest. The melting water formed will fill crevasses and other cavities in the ice and thus again be subjected to a lesser pressure, which, in its turn, results in its freezing once more. By this means the ice layer in question becomes more compact and clear than it was before the process began, and the freezing taking place under pressure, the crystal axes become orientated in the direction of pressure. However, in the course of time the cavities will be filled, and so will no longer be able to absorb the water formed by melting which, therefore, will turn to the side where the pressure is least, that is, where the ice is thinner. Thus, where the melting takes place, there is a decrease of volume which, again, produces a subsidence of the superincumbent layers. Further, from the thicker portions towards the thinner, a transport of ice takes place, not only in a melted, but also in a solid form, because there is a pressure in the direction already mentioned. This, it is true, is the case in all ice layers, but only in those where the cohesion is weakened can displacement of the ice particles or the admixed rock fragments take place, and this means in the very lowermost layers where the greatest amount of melting water is to be found. Otherwise Drygalski is of the opinion that it is not only a question of a mechanical shifting, but also of the transmission of a state, which takes place in such a way that in a given spot the ice was first melted and the water forced out to a place where the pressure was less or the melting point higher, and where, therefore, the water could freeze once more; the heat thus released might then cause other masses of ice to melt, which latter might again freeze in layers under a lower pressure and so forth. In the lowest and least cohesive layers the movement takes place at the greatest rate, but as it is not completely separated from the superincumbent layers, it communicates its rate of motion to the latter part and thus upwards through the layers. In this manner, although the proper motion is greatest in the bottom layer, the actual rate of motion is greatest at the surface, the rate of which becomes, not the sum of all the underlying layers, but the sum of portions of the latter. Where the ice is so thin that

throughout the mass it is cooled below the melting point of the surrounding air, the movement stops, and a rise of the surface of the ice takes place, the very fact which was brought out by the measurings in the outermost marginal zone. Also the blue ribbons Drygalski regards as being formed by alternate melting and freezing under pressure, but whereas the layers are the planes on which the water freezes under an approximately constant pressure, as is shown by the orientation of the crystals, the ribbons are regarded as being formed on "die Flächen auf welchen die Zustandsänderungen erfolgen." It is, however, difficult to understand how two such sets of pressure planes can be formed, as the pressure-forces present in a movable mass must be united in a resultant, Drygalski himself calls attention to this difficulty, admitting that the two sets of planes sometimes pass into each other.

Future investigations must determine to what extent Drygalski's theory can contribute towards explaining the phenomena connected with the movement of the ice. The facts in support of it are, first and foremost, the unfortunately rather isolated observations of the orientation of the crystal axes in the layers and the subsidence of the bottom layer in the Agssakâq Glacier. But its universality as an explanation of the motion of the ice is refuted by J. P. Koch's temperature observations in Storströmmen, from which it appeared that movement can take place in a glacier whose entire ice mass has a temperature below the melting point. Besides, it is not really clear what is Drygalski's idea as to the origin of the high temperature in the interior of the ice, as the thickness of the inland ice surely cannot be supposed to be so great that the pressure alone is able to cause a rise of the temperature to the melting point, and a transmission of heat from the earth is, in Drygalski's opinion, excluded. And, finally, it is difficult to reconcile this theory with the ideas—based upon observations both in and outside Greenland—on the connection between stratification and motion, which will be mentioned in detail in the following.

In the fronts of several of the glaciers visited by Chamberlin in 1894 certain of the layers of ice jutted out over others very sharply. It gave the impression, at first sight, that the upper layers had been thrust forward over the lower ones. Observations at South Point Glacier on Red Cliff Peninsula showed that in most cases the under layer was darkened with débris and that it was there disposed to melt more rapidly than the overjutting layer which was usually white and free from débris. There was further evidence of the like import in the fact that in many cases the overjutting cornice, when traced right and left, was found to disappear simultaneously with the disappearance of the débris in the under layer. On the other hand, in a very pronounced case of overjutting, reaching an extent of two to three feet, the junction plane between the upper and lower layer was corrugated and was marked by a thin line of earthy and rocky material. Not only the

débris layer was corrugated, but for some inches below there were blue laminations of clean ice, which were corrugated harmoniously with it. Similar phenomena are described from Qaqortoq Glacier and Tugto Glacier. In the latter the over-projection reached an extent of twelve or fifteen feet, and it was here observed that the under sides of the projecting layers were distinctly fluted. It appeared, however, that to some extent at least the fashioning of these flutings was due to the action of waters descending the face of the glacier and flowing backward on the under side of the projecting

Fig. 18. Glacier front with overjutting layers. Tugto Glacier, Bowdoin Bay, North Greenland (Salisbury).

layer. Everything considered, Chamberlin is nevertheless of the opinion that this over-projection of some layers over others is partly due to the movement of the layers across each other.

Also Barton found, in the Ũmánaq District, that the overhanging marginal faces were in many cases due to a shearing motion of the upper layers over the lower. "This was indicated quite strongly in one instance, where a layer projecting slightly beyond the ones above had caught a little detritus as it rolled down. This same ledge continued from the slightly inclined face along a portion of the overhanging face, and here still the detritus remained which had been caught in its descent, before the shearing motion had changed this part of the face to an overhanging one [1]."

[1] Journal of Geology, V, 1897, page 650.

As contrasted with this view Salisbury arrived at the result that where such overjutting layers occurred, there was always a thin layer of débris between the layers; where for some distance the overhang was interrupted, the layer of débris was also lacking, and the amount of overhang all along was, in a general way, proportional to the amount of débris. Consequently, the overhang must be the result of unequal melting, due to the unequal distribution of débris.

The conception of the movement in Storströmmen, which J. P. Koch formed by means of his detailed investigations of this glacier, is as follows: The movement is a gliding one, by which the glacier is split up into crevasse and fissure systems, mainly passing in the direction of motion. These systems of crevasses form gliding planes. Under certain, commonly occurring circumstances the ice along the gliding planes is transformed into compact ice.

J. P. Koch, however, does not reckon only with displacements along the vertical crevasse systems. An elevation in the underground may give rise to the formation of oblique or horizontal gliding planes, the ice above the upstanding part jutting out over the ice lying in front of the elevation. It is in this manner that moraine material from the bottom of the glacier is brought higher up in the mass of ice, thus producing the apparent stratification which is seen in every profile throughout the glacier. Chamberlin and Salisbury, who otherwise regard the movement of the glacier as a kind of "flowage," *viz.* a movement of the granules in connection with a momentary liquefaction of minute portions of the mass, also mention, as an auxiliary element, a glide along shearing planes. Starting from this presupposition there will be nothing to prevent regarding the overjutting of the layers, mentioned by Chamberlin, as a result of the different motion in the upper and lower layers.

It is interesting to compare this explanation with the theory, elaborated by Crammer, of the movement of the Alpine glacier. As demonstrated by this author the foliation in the glacier tongue is nothing but the folded and rolled-out névé stratification, so that the blue, compact foliæ proceed from the ice cover of the névé, the white porous ones from those of the snow layers. As the planes of layers or foliæ everywhere place themselves in the direction of motion, and frequently are of a polished appearance, it is probable that the ice moves by means of the foliæ gliding past each other. Besides, according to Crammer, displacements take place along horizontal or nearly horizontal shearing planes, which frequently at the end of the glaciers are seen to cross the foliation.

As to the first link in Crammer's theory, the transformation of the névé layers by folding—in consequence of the pressing together in the narrow glacier valley—J. P. Koch also has observed foldings in Storströmmen's layers of ice, which he seems to regard as the primary ones, or, in other

words, the stratification of the névé, but there they are crossed by the blue ribbons and by the gliding planes, now vertical now horizontal (fig. 19). The original surfaces of the layers here seem to be of no import as gliding planes, whereas in the Alpine glaciers, according to Crammer, they play a principal part. But a formation of blue ribbons or foliæ also takes place in the Arctic glaciers, and here in close association with the movement. One might feel tempted to ask whether they are not formed in the same manner in the Alps, *viz.* independently of the original division of the névé into ice and snow layers [1]. The much debated problem of the connection

Fig. 19. Ice margin at Cape Bellevue with dark bands of compact ice crossing the stratification (J. P. Koch and Wegener).

between the stratification and ribbon structure of the névé then becomes a question of the part played by the former in the motion of the glacier, and for the time being the only answer, which can be given, seems to be that in this respect there is a decisive difference between the Alpine and the Arctic glaciers. Perhaps future investigations will modify the answer in the direction that, in glaciers the breadth of which is very slight as compared with their névé area, the compressed, vertical layers of névé form natural gliding planes, while in relatively large glaciers they cannot assert themselves beside the fracture planes, which it seems are formed particularly under the influence of the topography of the under ground. However, temperature conditions also play a part. Where, as in the Alps, interchanging

[1] In this context there is reason to mention the observation of Drygalski as to the re-formation and disappearance of the blue ribbons in a given place on the surface of the glacier.

layers of snow and ice are formed from the start by partial melting and regelation, the granules also during the subsequent transformation of the whole mass into ice will be less intimately united along the limits of the layers than within the individual layers, and therefore displacements are rather apt to take place along the layer surfaces.

It has been mentioned previously that also in the horizontal stratification, to be observed at the ends of glaciers, interchanging laminæ of porous and compact ice (blue ribbons) intrude. In Storströmmen an investigation of the relation between the lamination in the lower part of the glacier end and the vertical ribbon structure was excluded because the glacier terminated in the sea with a calving wall, which presumably is 200—250 m high, of which only up to 30 m above sea level.

The fact that in the greater part of Greenland no melting of the névé takes place in summer, as a rule excludes the conception that the compact layers, the blue ribbons, the horizontal as well as the vertical, can generally be said to proceed from the ice cover of the névé and the porous parts of the snow layer.

Rate of Motion. The largest Alpine glacier, Aletsch Glacier, which is furthermore one of the most rapidly flowing, has a maximum rate of motion of about 0.5 m per day. The rate of the Alpine glaciers generally ranges between this value and a tenth of it, and the same applies to the rates of glaciers, fed from the local ice caps, which have been measured in Greenland; a great number of measurings in such glaciers have been undertaken by Steenstrup [1]. When, on the other hand, we are dealing with the large lobes from the inland ice, the motion is expressed in figures of an entirely different magnitude. The highest rates are naturally encountered in the glaciers of the large ice fiords, their productivity being due to their rapid advance in connection with their great thickness.

In the most famous of the ice fiords, that of Jacobshavn, Helland, in 1875, determined the rate of motion at a distance of 1050 m from the south side as a little less than 20 m within the twenty-four hours; as the breadth of the glacier is about 4500 m, it is probable that the rate of motion in its middle part will be still greater. A single determination by Engell, in 1902, yielded 22.8 m per day at a distance of 4 km from the side. In 1880 Hammer undertook determinations of the rate of motion from a point on the south side of the glacier, 4—5 km farther up the fiord than Helland's place of observation, and it is interesting to compare the two sets of measurements.

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[1] M. o. G. IV, page 82 ff.

Helland 1875.		Hammer 1880.	
Distance from margin of glacier	Movement within 24 hours	Distance from margin of glacier	Movement within 24 hours
400 m	14,7 m	280 m	5,2
420 -	15,4 -	550 -	7,5
445 -	15,2 -	615 -	9,2
449 -	15,2 -	875 -	12,5
1049 -	19,8 -	875 -	12,3
1059 -	19,5 -		

From this it seems to appear that the rate of motion increases towards the end of the glacier.

A similar maximum rate of motion—about 20 m per day—Moltke and Jessen found in the western glacier of North Sermilik (South Greenland), but it is in no wise the highest rate of motion observed. In 1886 Ryder, from a point at the edge of Upernivik Icecurrent, demonstrated a rate of motion of 31 m per day, and during part of the time of observation, which extended over a little less than twenty-three hours, the rate of motion even corresponded to 38 m per day. Generally speaking the rate of motion for all the points measured proved very irregular, and this impression was intensified by the new measuring, undertaken by Ryder in April, 1887, where the highest rate found was merely 10.3 m per day. This might be considered a proof that the rate of motion of the glacier in spring, when the cold has penetrated farthest down into the ice, is essentially slower than in summer, when a greater portion of the mass presumably has a temperature near the melting point. But then the measurings of Steenstrup yielded the result that at any rate the large glaciers did not move at a much slower rate in spring than in summer, whereas in the case of the smaller glaciers some diminishing of the rate of motion could be observed in the course of the winter. Also, according to Drygalski's determinations of the rate of motion at Great Qarajaq, this was the same summer and winter, with a highest rate of about 20 m per day. Further, the rate of motion within the surface proved to increase towards the end of the glacier, which is the opposite of what is the case in the Alpine glaciers. From the shape of the valley Drygalski feels justified in drawing the conclusion that the thickness of the glacier increases towards its end, so that the lower surface movement in the upper reaches of the glacier cannot be due to a greater cross-section area, and he, therefore, supposes that in the upper cross-sections the rate of motion must be greater in the deeper layers than in the lower cross-sections, an explanation which harmonizes with the formerly described view of the same author as regards the mechanics of motion. As mentioned above, there has, also elsewhere in Greenland, been demonstrated an increase of the rate of motion towards the end of the glacier, but as in this and other cases it is constantly a question

of glaciers calving in the sea, the explanation must in all probability be looked for in the diminished resistance against motion, which results from the fact that the extreme end of the glacier is entirely, or in part, kept floating by the water and, through the discharge of icebergs, is subject to a stronger ablation than the portions of the glacier lobe situated behind it, which are only subject to melting and evaporation.

From the glaciers in the large ice fiords the following figures may further be given. In Itivdliarssuk Steenstrup, at the beginning of April, found a maximum rate of motion of 14.4 m per day, Drygalski in July a maximum rate of motion of 16.3 m or practically complete harmony. The northern glacier of Torssukâtak, according to Helland, moves 10 m per day in the middle.

The glaciers of Northwest Greenland seem, on an average, to be distinguished by an extremely low rate of motion, but accurate measurings are almost entirely lacking. Peary determined the rate of motion in Bowdoin Glacier (lat. 77° 40′ N.) at a little less than 1 m per month, and yet that is a glacier which, according to Chamberlin, "discharges icebergs of considerable dimensions."

Steenstrup attempted to determine the smallest thickness which an ice mass must have in order to be able to move like a névé or a glacier. In various localities on Disko and Nûgssuaq Peninsula he and Hammer measured the thickness of the snow cover in places where the rocky wall below was too steep for a glacier to form, and where the snow therefore fell down as soon as it began to move, and they found the following values: 46.4, 41, 61.8, 40.8, 38.7, 36.6, 45.2 and 43.2 m. As the figures, with one exception, are in such close harmony, he concludes that the névé must have a minimum thickness of thirty odd metres in order to move. In the same manner he measured the thickness of a number of small calving glaciers, finding the following values: 74, 43.5, 51, 31.3, 41 and 45 m, the minimum thus also in this instance seeming to lie a little above 30 m.

It was also Steenstrup who first attracted attention to the so-called "dead glaciers," which he particularly observed on Disko Island and Nûgssuaq Peninsula. By a "dead glacier" he understands a glacier which by melting off has lost its connection with the névé and thus its power to move. When an ice mass of this kind, for a long period, is cut off from a supply of new ice, its surface becomes gradually covered by moraine material which has been melted out and, on the other hand protects the remaining ice from being warmed by the air, so that it is able to remain for many years. The glacier attains such a striking likeness to a moraine that one may ascend it without discovering that it is in reality a glacier. The ice nucleus frequently manifests itself by accumulations of water being found on it, or by dark, damp streaks along the sides. If the névé in which the "dead" glacier originates once more becomes able to feed a glacier, it will frequently happen

that the new glacier moves across the old "dead" one. Steenstrup mentions examples of such glaciers from Nûgssuaq Peninsula, and perhaps the same explanation holds good of several of the instances mentioned by Chamberlin, where a glacier apparently moves out across its own terminal moraine.

In the above, mention has only been made of the movement in the narrower or broader lobes of ice which, in the form of glaciers, project from the edge of the inland ice. As to the movement of the inland ice proper, only sparse investigations have been made. Off Qarajaq Nunataq, between the glaciers Great and Little Qarajaq, Drygalski determined the rate of motion at 0.1—0.3 m per day, but its direction was practically parallel with the edge of the land, that is towards Great Qarajaq, or in other words, the movement is influenced by the glacier. Besides this horizontal movement a vertical movement was demonstrated, as has been mentioned in connection with Drygalski's theory on the mechanics of motion.

At Nunap Kigdlinga, where the Swiss expedition of 1912 ascended the inland ice (lat. 69° 40′ N.) Mercanton, in July—August, 1912, undertook measurings of the movement of the ice. Here the margin of the inland ice lies at a height of about 550 m above sea level, and it rises in a snow-covered slope with an inclination of about 35° and crowned by a moraine, the culmination point of which is 614 m; behind it the ice slowly rises towards the interior. The direction of the motion was almost at right angles with the margin, though with a slight deflection towards the glacier Sermeq Kujatdleq. The movement, as was to be expected, proved to be extremely slight. On the moraine itself the rate of motion was 0.65—0.75 cm per day; for points lying 0.3—2.1 km behind the moraine, it ranged between 3 and 6 cm per day.

Oscillations of the Ice margin. The variations of the length of the Greenland glaciers attracted the attention of scientists, at an early period, and in various places accurate determinations have been undertaken of the position of the edge of the glacier, and this has made it possible to establish the extent of the changes which have taken place. The facts hitherto proved cannot be said to be regulated by any law, as advance has taken place in certain places at the same time that the glaciers retreated in others, and periods of advance and retreat of greatly varying length have succeeded each other. Within limited areas a certain homogeneity can at times be traced as regards the changes of the position of the ice margin, but in other cases two glaciers situated close to each other and fed by the same local ice cap move in opposite directions. Beginning in the north, we will, in this context, give briefly some of the exact determinations. In the years 1917—20 the Hiawatha Glacier on Inglefield Land advanced 400 m and then in 1920—22 retreated 700 m, and this process, *viz.* advance until 1920 and afterwards retreat seems, according to Lauge Koch, to be typical of the Cape

York District. However, exceptions also occur. Thus, Brother John Glacier at Etah, according to the descriptions given by Kane, Hayes, Bessel, Senn, MacMillan, Lauge Koch, etc. seems to have been constantly advancing within the period 1854—1922. On the other hand, Moltke Glacier in Wolstenholm Fiord retreated 2.6 km in the period 1916—23.

From various observations, which have partly been quoted in the preceding, observations on the cryoconite horizon and on the ablation, which exceeds the measured rise of the marginal portion of the ice on old and new moraines, etc. Drygalski concludes that the inland ice is in a state of constant retreat, though he is unable to demonstrate any change in the position of the ice margin within the period of observation.

On Nûgssuaq Peninsula several glaciers have been made subject to such observations. In 1850 the distance of Agssakâq Glacier from the sea was estimated by Rink at 250 m, but in 1879 by Steenstrup at 1150 m. A statement by Helland in 1875, to the effect that the distance should be 500 m, is of less value, as it is not shown clearly by his words to which point he has measured, but from his description of a large "dead" ice mass in front of the actual glacier, it clearly appears that the latter had retreated very much since Rink visited it. On the other hand, the glacier, when Steenstrup visited it, seemed once more to be advancing across the moraine masses below it, and this advance continued during the following years, so that the margin, when Drygalski saw it in August, 1892, lay at a distance of 25 m from the sea, and the following year it had further advanced 8 m.

Sermiarssuk Glacier, which derives from the same névé as Agssakâq, is described alike by Rink, Helland and Steenstrup as terminating in the sea in a steep wall, which Steenstrup measured at 43.5 m in height, whereas when Drygalski visited it in 1892 and 1893, only the right half formed a steep wall, the height of which was 10—15 m, while the left dropped down to the water with a curved surface. Further, the front had retreated somewhat, about 10 m, a retreat which, though slight, is interesting, considering it has taken place within the same period, in which the Agssakâq Glacier advanced so considerably.

The distance of Little Umiartorfik Glacier from the sea was estimated by Rink, in 1850, at 380—500 m; Helland, in 1875, gave it as 322 m, and Steenstrup, in 1879, determined it at 230 m. Thus there seems to have been a slight advance, for the last four years corresponding to 6.3 cm within the twenty-four hours, which (according to Steenstrup) is about half the daily movement of the ice.

Sarqaq was described by Rink as being in a pronounced state of melting; the outer end was quite buried under gravel, and only at a distance of several hundred yards from the shore was the solid ice seen to peep out. Helland found the glacier extending into the sea with a front about 25 m in height, and it presented a similar appearance in April 1879, while in August of

the same year the end of it had partly collapsed and been covered by moraine.

In Blæse Valley on Disko Island two of the small glaciers on the west side have been subjected to careful measurings in connection with mapping and photographing, in 1897 by F. Froda [1], in 1912 by Mercanton and again by F. Froda in 1923. The most southerly of the glaciers, which already in 1897 seemed to have retreated somewhat since Chamberlin's visit in 1894,

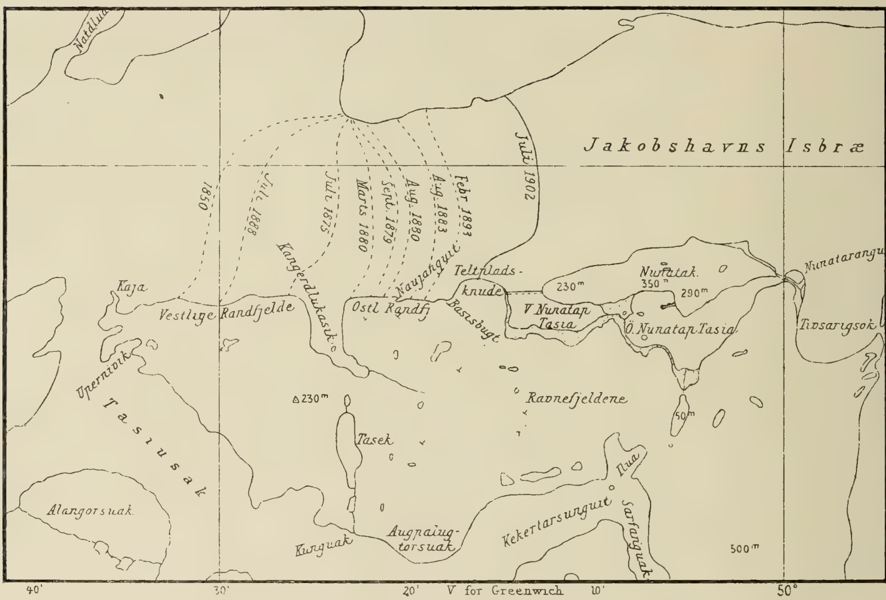

Fig. 29. Oscillations of Jacobshavn Glacier (Engell).

within the period 1897—1912 retreated 70 m, within the period 1912—23 150 m; its margin in 1923 was very thin, only a few centimetres, and it seemed to be quite "dead." The most northerly glacier within the same two periods retreated 80 and 70 m respectively. Finally, a glacier on the opposite side of the valley showed a retreat of 40 and 20 m respectively. When it is borne in mind that it cannot be decided whether the movement was continuous in the period 1897—1912, the figures suggest an increasing rate of retreat in the case of the former glacier and a diminishing rate for the other two, a further proof that purely local causes exercise an extremely great influence on the glacial oscillations.

The most impressive variations are those to which the margin of Jacobshavn Glacier have been subject. Between Rink's visit in 1851 and Helland's in 1875 the margin of the ice retreated more than 4 km. When in September 1879 Hammer first determined the position of the margin, it lay about

[1] v. Frode Petersen.

2 km farther east. In the course of the winter it again advanced a little, so that in March, 1880, it was about 1 km farther west than six months previously, but then in the period until August 1880 it retreated about 2 km towards the east. Four years afterwards Hammer again had the opportunity of observing the ice margin, which then had further retreated about 1.5 km. The next traveller to make investigations at Jacobshavn Glacier was Drygalski, but his indication of the position of the margin in 1893 is too inaccurate to permit of deriving anything therefrom, except the fact that the retreat had continued, although at a diminished rate. But after that the retreat again became more rapid, so that the margin, when mapped by Engell in 1902, lay 4 km farther east than when mapped by Hammer in August, 1880. All in all, Jacobshavn Glacier has thus since 1881 been shortened by about 11 km, and also other glaciers in the neighbourhood bear distinct traces of retreat.

Besides these facts regarding glacier oscillations in Greenland, which are based upon repeated measurings, we have a number of reports from natives, to the effect that the ice in such and such a place has had a different distribution from the one it now has. Thus Holm quotes an account of how a glacier in Ilua Fiord, Julianehaab District, was said to be advancing rapidly and, within living memory, had buried a group of old Norse ruins; similar reports are also mentioned by Ryder from the Ũmánaq District and by Jensen from the Sukkertoppen District, while according to other reports the ice is in a state of retreat. Some of these reports are quite fantastic, such as the frequently repeated tales of a sound right across Greenland which has been closed by the growing inland ice, and where other criteria are lacking, one should not build too much on statements of that kind.

ICEBERGS.

As far as can be gathered from the older accounts available of the inland ice of Greenland it has not, within historic times, undergone any change in thickness and extent, although, as mentioned in the preceding chapter, local progress and retreat of the ice margin have taken place. Roughly speaking, the inland ice must, consequently, be regarded as stationary, and the supply which it receives in the course of the year through precipitation, almost exclusively in the form of snow, must thus be counterbalanced with what is wasted in various ways. By far the greater part of the supply is undoubtedly carried away in the form of melting water, while a not inconsiderable amount is wasted in the form of icebergs. The ratio between the masses of ice which are carried away by these methods it is impossible to compute, as data concerning the amount of water conveyed by the rivers are entirely lacking, but it is to be presumed that the icebergs form a fraction of the magnitude 1 : 10 of the total yearly wastage.

Although along all the coasts of Greenland glaciers come right down from the inland ice to the fiords or immediately to the sea, icebergs are only produced along comparatively limited stretches. The greater icebergs either proceed from the west coast north of lat. 69° N., or from the east coast south of the same latitude. A special part is played in the production of icebergs by the so-called ice fiords, by which are understood fiords into which particularly productive glaciers debouch. Rink regarded the ice fiords as old mouths of rivers through which the surplus of precipitation from a larger area of the inland ice was carried out to the sea, and this view undoubtedly contains a nucleus of truth. Thus, according to Drygalski's computation, the annual production of ice of the glacier Great Qarajaq alone amounts to about 15.3 km^3; if the annual precipitation within the area in question is supposed to correspond to 50 cm—which figure is hardly too low—this means that the production of icebergs from this glacier represents the draining of an area of 30600 km^2; add to this the melting water which flows away below the ice and which presumably represents a quantity of water several times greater, and the total area drained through Great Qarajaq is undoubtedly of an extent which may very well correspond with that of a larger river system at the time when Greenland was not yet ice-covered.

From the dimensions of the icebergs produced Rink divided the ice fiords into four classes, the first class comprising those which produced the greatest icebergs, whereas in the ice fiords of the fourth class only small pieces of ice were formed, the so-called calved ice. According to Rink the first class comprised five ice fiords on the west coast, *viz.* those of Jacobshavn and Torssukátaq in the interior of Disko Bay, of Great Qarajaq and Karrat in North-east Bay and of Upernivik in lat. 72° 55′ N., the latter, however, according to Drygalski and Lauge Koch, having unjustly acquired the reputation of being particularly productive. But apart from the ice fiords rather considerable icebergs are also discharged from the glaciers of Melville Bay, four of which, according to Lauge Koch, are especially productive, *viz.* Steenstrup Glacier, Diedrichson Glacier, Nansen Glacier and King Oscar Glacier. In 1920 these four glaciers discharged icebergs of an extent of more than 150 km^2 which was, however, undoubtedly several years production. On the other hand, more than half of the total glacier front of Melville Bay may be considered stationary. The glaciers of the west coast, north of Cape York, only produce insignificant icebergs; most of them, for instance the huge Humboldt Glacier, move extremely slowly.

On the east coast, south of lat. 66° N., Garde reckons the following glaciers as being of the first class: Sermilik, Ikerssuaq, Pikiutdleq, Igdlutuarssuk, Tingmiarmiut and Anoritoq, and he further emphasizes the fact that both the number and extent of smaller glaciers along this distance far surpasses what is met with in West Greenland in the same degrees of latitude. Finally, according to the Eskimos, the greatest and most productive glacier

on the east coast is to be found in Kangerdlugssuaq Fiord in lat. 68° N. approximately. From Blosseville Coast as far as Germania Land all glaciers issueing from the inland ice terminate at the heads of deep fiords; some of these, for instance in the Scoresby Sound Archipelago, produce very large icebergs which, according to Ryder, are characterized by their massive box-like shape, but owing to the lower depth at the mouth of the fiord they rarely reach as far as the sea.

Nor are icebergs met with along the coasts of North Greenland, but here the reason is that the sea ice never breaks up or only at intervals of many years. A permanent thick layer of ice on the surface of the fiord or the sea prevents the icebergs which may possibly form from floating away; they remain, where they have been formed until they melt. But the case most commonly occuring in North Greenland is that no icebergs are detached at all from the glacier, as the solid sea ice offers such strong resistance to its movement. The sea ice, naturally, cannot prevent the glacier from pushing out, but the outermost portion of the glacier tongue floats on the water without losing its continuity, and owing to the melting off it is flattened so much towards the end as practically to merge into the sea ice. As cases in point may be mentioned the glacier in Petermann Fiord, the extreme 40 km of which float on the sea, and the edge of which is only 2 to 5 m high, and Ryder Glacier in Sherard Osborne Fiord. In front of Jungersen Glacier in Nordenskiöld Fiord and Academy Glacier in Independence Fiord several detached icebergs are to be found, and they suggest that at least several times within each century there is open water that enables the icebergs to float away. The floating portions of these two glaciers are composed of densely packed icebergs. In other words, they are formed by regeneration, crevasses having undermined the whole glacier before it began to float. Of far greater extent than the floating glacier tongues of the north coast are the formerly mentioned floating glacier or inland ice tongues in Jökel Bay and Seventy-nine Fiord in the northern part of the east coast.

In the ice fiords where the great icebergs form, there is naturally also a very considerable production of smaller icebergs and of calved ice. As, owing to the great supply of melting water, there is always a more or less powerful current out of the fiord, the detached icebergs will sooner or later be carried out of the fiord, apart from the above-mentioned cases where they are held fast by a permanent cover of sea ice. However, the inner waters are closed by the sea ice for more than six months, and the whole of the yearly production of icebergs is thus carried out of the fiord in the course of a few summer months. The melting and crumbling of the winter ice progresses from without inwards, and at last the belt of winter ice is too narrow to hold the pressed-up wall of icebergs and calved ice which in the course of winter has accumulated in front of the glacier; it breaks suddenly, and the whole mass rushes out through the fiord at a great speed.

This phenomenon, which generally has the character of a catastrophe, is called by the Danes in Greenland the "shooting out" of the fiord after which, owing to the drifting masses of ice, the fiord may be unnavigable for several weeks, but it is gradually being more or less emptied, thanks, not least, to the strong föhn winds which sweep it clean.

The form of discharge described here is typical of most of the ice fiords of West Greenland. Porsild calls it the Torssukátak type, after the great ice fiord Torssukátak, where it occurs in a pronounced form, and he mentions as its peculiar characteristics: "A long, quiet winter stage and a short summer stage, inaugurated by a single shooting out." But besides this he sets up as a type apart the Jacobshavn Icefiord, which lacks the pronounced winter and summer stages and is characterized by numerous discharges. Here a bank is situated at the mouth of the fiord, on which there is always a quantity of closely packed, large icebergs; from the size of the grounded icebergs, Hammer estimated the depth of the water above the bank as being, at least, 250 m. When a discharge has taken place, the ice masses are pushed out, and particularly the larger icebergs are stopped by those which are already grounded. Therefore, the fiord is not entirely emptied and, according to Porsild, this is the reason why the discharges in this place succeed each other more rapidly, there being less room for the packing of icebergs in the interior of the fiord than there would be after a complete emptying out. On an average there are about ten discharges in the year. They most frequently coincide with a strong tidal water, are rarest during the coldest winter months and most powerful in June. As the propelling power in the shooting out Porsild regards the accumulation of water at the head of the fiord which must be caused by the accumulated calving products, whereas the actual detachment takes place through the agency of the spring tide.

As already mentioned, pieces of ice are loosened from the margin of the inland ice, where in the shape of glaciers it pushes down to the sea, these pieces of ice being of all possible dimensions, from mere granules to icebergs of many millions of cubic meters. The tallest icebergs originate in Jacobshavn Glacier and not infrequently measure more than 100 m above the level of the sea. Thus Helland measured a berg of 122 m, and another of 89 m, and he mentions 70 m as a common height for a large iceberg; the largest of all he estimates at a volume of 21 million m^3; Hammer measured two af 104 and 108 m respectively and estimates the volume of the largest iceberg encountered in Jacobshavn Icefiord at 1000 million cubic feet (31 million m^3). From Jacobshavn Icefiord Drygalski gives, *inter alia,* the following heights: 137 m, 102 m, 101 m and 100 m; from Great Qarajaq: 97 m, 92 m and 85 m; from Little Qarajaq: 16 m; from Itivdliarssuk: 72 m and from Karrat Icefiord 81 m. Steenstrup determined the altitude of an iceberg from Great Qarajaq at 76.6 m and calculated its volume at 18 million cubic metres. Heights like those of the greatest icebergs mentioned above

do not seem to occur along the east coast. Garde measured an iceberg of 60.5 m, but is of the opinion that the altitude may be towards 100 m; the cubic content of the measured iceberg he gives as 6 million m³. Amdrup estimates that the largest icebergs were 50 to 65 m in height and about 1000 m in length.

From the observations of the "Danmark" Expedition we know that the icebergs in the coast sea north of 74° latitude are small and rather rare. Only in the interiors of the fiords, where open water is formed regularly every summer, do we find the conditions necessary for the forming and breaking loose of icebergs, and only the glacier Storströmmen in Dove Bay has a production which can be compared with the greater glaciers of West Greenland. A single iceberg which was grounded at a depth of about 90 m, was measured and proved to be 36 m above the level of the sea, a rather surprising result, as the ratio of the portion of an iceberg projecting above the water to the immersed portion is generally estimated as nearly 1 : 7.

As regards the altitude of the icebergs it should be borne in mind that the latter is no direct measure of the height of the glacier wall from which the iceberg has broken loose. For by far the greater number of icebergs constantly change their position in the water under the influence of unequal melting and the consequent shiftings of the point of gravity, and this also has some bearing upon the immense variation in the shapes of icebergs, which at all times have enchanted the spectator, and which makes any attempt at classifying them almost hopeless. Castles and churches, domes and spires, columns and arches, amphitheatres and massive cubes are only a meagre selection of the comparisons which have been used to describe the impression made by this immense natural phenomenon. According to Chamberlin the Jacobshavn icebergs are noted for their pinnacled and angulated forms, and he adds: "It is even held by Greenlanders that they may be distinguished from the bergs of other glaciers by their distinctive forms." This statement naturally only applies to icebergs which have not toppled over, but still turn the original surface upwards. As to the Steenstrup Glacier in Melville Bay, Lauge Koch says that the icebergs occurring there, the altitude of which is about 25 m, are quite different from those of all South Greenland glaciers; they are in reality great portions of the floating glacier end, which suddenly become detached and for a long time keep in an upright position before they are split up and overturned. This also seems to apply to the other great glaciers of Melville Bay and to Moltke Glacier in Wolstenholme Fiord.

For a few glaciers figures are available as to the total production of calved ice and icebergs. Thus Helland estimates the daily production of the Torssukátak Glacier at 6.3 million m³, which gives a yearly production of 2.3 km³, and for Jacobshavn Glacier he proves the daily production to be 16 million m³ or corresponding to a yearly production of 5.8 million km³. However, Drygalski is of the opinion that Helland's estimate, at any rate

as far as Jacobshavn Icefiord is concerned, is far too low, the figure being much below the value which Drygalski, based on very careful measurements, demonstrated in the case of Great Qarajaq, *viz.* 15.3 km^3 annually.

The very process by which the icebergs are formed or detached, the so-called *calving*, has for many years been a much debated one in the literature dealing with this subject. The original conception is undoubtedly that the glacier, when pushing out from land into the sea, loses its support, the outer extremity then breaking off because of its own weight. The tacit presupposition of this is, however, that the glacier has a greater slope than the surface on which it moves, which presupposition will naturally only be fulfilled under quite special topographic conditions, but which was rather obvious in an older period when ideas were less clear as to the formation of valleys and the genetic connection between the existence of the valley and the glacier.

However, in 1852, Rink set forth quite a different explanation of the calving process, *viz.* that the glacier shot out on such deep water that the end of it, owing to the greater weight of the water, was made to float and finally, broke off, by the buoyant action of the water, the pieces, in their turn, rising in the shape of icebergs. It was particularly through his observations at Jacobshavn Icefiord that Rink arrived at this theory, which he also found corroborated by the fact that the Greenlanders had two different terms for the manner of formation of icebergs, *viz. îgarpoq*, "inclines backwards" and *nâkarpoq* "falls down from something." In a series of later writings Rink maintained and defended his theory, particularly as far as concerns the formation of the *large* icebergs, while at the same time admitting that under certain circumstances also other manners of formation might obtain.

This view set forth by Rink was shared, for instance, by Helland and Hammer. Helland on two occasions had an opportunity of observing calvings, *viz.* once at Jacobshavn Glacier and once at Torssukátak Glacier. In the former case his attention was roused by "a terrific crash," and he then saw "an immense dentate piece of the glacier turning over and rearing its one edge high up in the air in front of the glacier; then, the moment it rose, large tower-like parts of the latter fell down, crumbling while they fell into little bits." Then calving began in another place: "A large piece of the solid glacier was detached and was seen to move with a velocity, which I estimate at 1 metre per second at least. On the following day one of the newly formed icebergs was measured and was found to be 89 m in height, the height of the glacier wall hardly exceeding 40 m." About the calving at Torssukátak Glacier Helland says: "A piece of the solid ice detached itself and rose in front of the edge, presumably to a height of 30 m, tilted over, and then suddenly crumbled into a thousand bits, as if it might have been sand. Of the whole iceberg only fragments of ice or calved ice were left." The height of the glacier front he estimates at about 15 m.

Steenstrup also shares the opinion of Rink in so far as he considers a main cause to be the buoyant agency of the water, but the motion and aspect of the glacier, the gradually sloping, vaulted and greatly crevassed surface seem to him irreconcilable with the fact that the end of the glacier should be floating on the water. Instead of that he thinks that the glaciers are pushed so far along the bottom of the fiord as only to rest on it with a slight pressure, and that the calving is occasioned by the falling down of the portion of the glacier above the water, the buoyancy of the water then being made to act upon the submerged portion, which is broken up and rises to the surface in the form of icebergs.

Also according to Drygalski is "der Auftrieb des Wassers die eigentliche Ursache für die Loslösung der Eisberge [1]". Otherwise he distinguishes be-

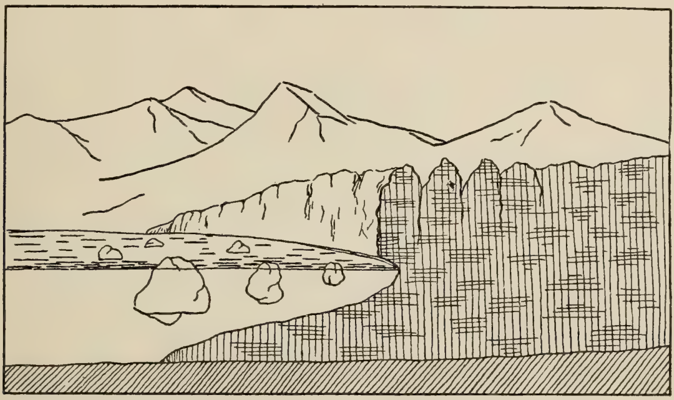

Fig. 21. Origin of icebergs after Russell (Hobbs).

tween calvings of the first, the second and the third class. The latter, which only supply small icebergs or calved ice, simply consists in pieces of ice falling down from the edge of the glacier. As calvings of the second class he mentions a peculiar iceberg formation which he twice had an opportunity of witnessing; he first heard an immense noise, and then an iceberg suddenly emerged from the water, "eine ganze Strecke von dem Rande des Eisstroms entfernt," and accompanied by a continuous din it turned round, until it attained its equilibrium, at the same time moving away from the ice margin at a fairly great speed. The phenomenon presumably corresponds with the one described by Russel, an illustration of which is furnished by fig. 21. Through the agency of the higher temperature of the air and the beating of the waves the portion of the glacier above the water crumbles more quickly than the submerged part, so that the latter may project like a submarine tongue from which, by the buoyant agency of the water, fragments are torn off from time to time. It is thus the removal of material from the upper portion of the glacier which starts the process, and so Steenstrup's

[1] Drygalski, 1897, page 395.

calving theory is, to a certain extent, supported by the observations of Drygalski and Russell. On the other hand, Drygalski is not of the opinion that the falling down of ice from the edge plays any essential part in what he terms calving of the first class, that is to say, the proper formation of icebergs by which pieces are broken off from the whole height of the glacier front. This Drygalski had twice an opportunity of observing at Great Qarajaq, and he describes the process in the following manner: the calving begins by the front edge of the glacier rising, at a slow rate, considerably above its remaining portion. The iceberg then falls backwards in the direction of the glacier, rolling backwards and forwards until it has found its equilibrium. In the former case Drygalski found that the iceberg, after having come to rest, projected a little above the edge of the glacier; in the latter where a measurement was made, the height of the iceberg was only 49 m, that of the glacier front 89 m.

Of the glacier north of Wandel Land (Melville Bay) Lauge Koch says that its edge is lower than the icebergs situated outside it, a phenomenon which he has only observed at this glacier and that of Jacobshavn. When in his description of the detachment of an iceberg from Humboldt Glacier, Kane writes that "so far from falling into the sea, broken by its weight from the parent glacier, it rises from the sea," Lauge Koch disputes this statement, being of the opinion that Kane has simply transferred Rink's observations from Jacobshavn Glacier to Humboldt Glacier.

At Moltke Glacier in Wolstenholme Fiord Lauge Koch happened to observe a calving at close quarters, and he describes it in the following manner: "It began by the upper part falling forward. By this movement the ice below the water was split up, and the detached ice shot up like a shell, so that for a moment it was higher than the front of the glacier; then the piece fell forward and with great velocity shot out into the water."

During his ascent to Queen Louise Land, in 1912, J. P. Koch had an opportunity of witnessing a calving at the closest quarters, his camp being situated on the very glacier tongue which calved directly inside the portion that detached itself. In the course of the preceding days he had observed how the tidal water contributed towards extending the already formed fissures. At low water the fissures opened along their upper edges, and blocks of ice were flung down into them from the edges; then, at high water, the fallen masses acted as wedges, and instead of closing up the fissures along their upper edges the high water caused the iceberg below to break loose.

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PHYSIOGRAPHY OF WEST GREENLAND

BY

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INTRODUCTION: AREA AND BOUNDARIES

The area of ice-free West Greenland amounts to about 116,000 square kilometres. This is a little more than a third of the total outer land, but only a very small part of the country covered by the inland ice. In extent it is equal to England, exclusive of the Welsh and Cornish uplands, but, extending over fifteen degrees of latitude, it is longer than the distance from the Scottish border to Madrid. What we are dealing with is, consequently, only a long and narrow strip of land, at most 180 km in width and, further, broken by fiords and inlets or even split up into large and small islands.

The southern boundary towards the east coast of Greenland offers no difficulty. Of course it would be sheer pedantry to draw it from the exact point of Cape Farewell to the inland ice, *viz.* very nearly along the 44th meridian. On the contrary, the large islands of this region, Christian IV Island, Eggers Island, etc. make an undivisible whole, and the same also applies to the large peninsula formed by the Tasermiut Fiord from the west and Lindenow Fiord from the east. South of the 16 km broad isthmus between the heads of these fiords there is no continuous sheet of inland ice. Holm describes the western part of this peninsula as a glorious mountain scenery with huge glaciers coalescing, while the lower eastern part is covered with a layer of snow-clad ice, forming hills or valleys according to the underlying land, and above which all mountain peaks project. From a physiographic point of view the east coast of Greenland should, consequently, only be reckoned from Lindenow Fiord, which also coincides with the administrative division. The most southerly projection, Cape Farewell or Statenhoek (lat. 59° 45′ N.) is a rock 300 m in height and merely connected with the wild, mountainous country behind it by means of a narrow alluvial neck, while outside the promontory there are also some low islets and skerries.

The northern boundary of West Greenland, from an administrative point of view, follows the 74° 30′ N. latitude across Holm Island. The map, however, clearly shows that geographers should include Alison Bay and

the islands situated outside the latter, up to about lat. 74° 50′. Here the country gradually disappears, is, as it were, submerged into the sea or buried under the inland ice so that at last nothing remains but the monotony of the glacier, here and there broken by a nunataq.

The eastern boundary of the area naturally coincides with the margin of the inland ice and causes no difficulty, though it should be borne in mind that the ice margin is subject to oscillations and that solitary nunataqs here and there project above the marginal zone of the ice, forming the extreme outposts of the coast land against the great white desert. However, the most easterly point is not a nunataq, but Aluk (long. 43° W.), a small island north of Prince Christian Sound, which at one time was the meeting place of the Eskimos of West and East Greenland during their trading expeditions.

On the west the coast is washed by the waters of Davis Strait and Baffin Bay and there, at Kitsigsorssuit in the Upernivik District, reaches as far out as long. 57° 50′W. The apparently sharp line where sea and land meet is, however, not the one which to geographers is most natural. The coast land continues gradually in the continental shelf, which in several places extends far out to sea, before it falls off steeply towards the abyssal depths. The soundings taken in the Greenland waters are too few to permit of forming any distinct idea of the extent and relief of the continental shelf; but it seems as if its boundary towards the west, at any rate in some places, is at the isobase of 300 m. Also from other formerly glaciated areas a corresponding deep-lying boundary of the continental shelf is known, while otherwise it only extends to a depth of 200 m.

The surface of the shelf is, however, not a level plain. Deep channels, which are nothing but "drowned" fiord valleys, divide it into a number of banks, which in their turn are separated from the coast by other channels parallel with the latter. The bank off Julianehaab is situated at a depth of 100 or 200 m, up to 60 km from the shore. A few years ago another bank was located by the "Dana" off Ravn's Storö, a little north of the Frederikshaab Glacier. The Fylla Bank extending from Fiskenæs to Godthaab is rather narrow; but from there the shelf extends northwards in Little and Great Hellefiskebanke off Sukkertoppen and Holsteinsborg (fig. 1). Here the 300 m isobase is not met with until 270 km out in Davis Strait, and whereas off Godthaab the lead takes the bottom at a depth of more than 1000 m at a distance of 75 km from the shore, it here, at the same distance out, only shows 188 m. Great parts of the banks are less than 100 m in depth, and in some places the bottom is only 30 or 40 m below the surface. It is on these banks that the great halibut fisheries take place.

Off Disko there is a similar, smaller bank, and also off Svartenhuk Peninsula shallow water has been noted, but in the northern waters the soundings are too sparse to yield even the roughest estimate.

Within these boundaries West Greenland is incontestably the best known part of the country and upon the whole one of the most thoroughly investigated Arctic areas. Consequently, it would seem comparatively easy to render an account of its physiography, nor would it be difficult to make a purely descriptive enumeration of fiords, islands, etc. It is, however, a different matter when attempting to arrive at an understanding of the genesis of the land-forms, based upon an analysis of the elements of the landscape. In West Greenland, modern geomorphological views have only been brought to bear in very few cases and, even though the greater part

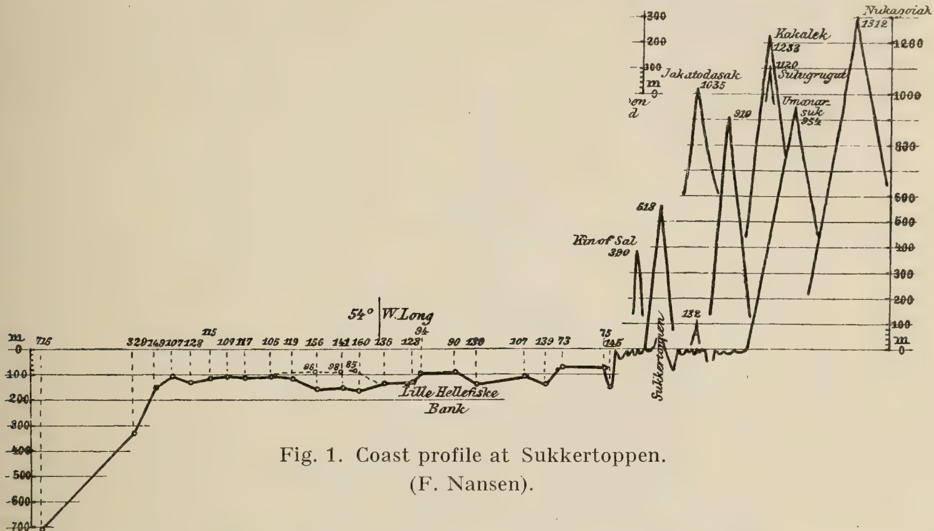

Fig. 1. Coast profile at Sukkertoppen.
(F. Nansen).

of the coast has gradually been visited by geologists, the results obtained, with very few exceptions, only yield a rough summary, and finally, geomorphologists receive no assistance from existing maps, as the latter are primarily sea charts without topographical details.

Add to this that we are here only dealing with a narrow coast-fringe of ice-free land outside the inland ice. The topographical types visible are merely like the extreme twigs of a tree, the trunk and main branches of which are hidden from our view. The inland ice conceals the natural key to the understanding of the coast scenery of Greenland, and it is doubtful whether, without this key, we shall ever be able to join the individual parts into a rational whole. It should be strongly emphasized that what is tentatively set forth in the following paragraphs is nothing more than an attempt.

NATURAL QUALIFICATIONS OF SCENERY

STRUCTURE OF THE COUNTRY.

Stratigraphic and Orographic Elements. Every landscape is a function of two groups of factors, in the first place the rocks forming its

structure, in the second the inner and outer agencies which have gone to shape this material. A landscape is an individual, not a chance conglomeration of mountains and fiords. In eternal interplay, constructive and destructive agencies have been brought to bear upon it from the earliest times. It is our task to draw a picture of the country as it is to-day, superficially untouched throughout centuries, for in the history of the globe a thousand years are like one day, whereas to the experienced eye it bears the traces of eons in its face.

The chapter on the geology of Greenland contains a stratigraphic summary of the components of the ground, and so we may content ourselves with summing up the rocks of West Greenland in the following chronological table:

Era	Period	Epoch	Rocks
Cenozoic	Quaternary	Holocene	Alluvial formations
		Pleistocene	Till, etc.
	Tertiary	Eocene	Basalt Shale, Sandstone
Mesozoic	Cretaceous	Senonian	Shale Shale, Sandstone
		Gault?	Shale
Paleozoic	Cambrian?		Granite, Syenite, Nepheline-Syenite Porphyry, Porphyrite Sandstone
Precambrian			Gneiss, Chrystalline Schists Granite, Syenite

It is supposed that the main lines of the present horizontal configuration are due to faults and, according to Wegener's theory on continental movements, West Greenland was only divided from Baffin Island within the Quaternary period, this division being caused by a fissure which since then has widened into Davis Strait and Baffin Bay. From the position of West Greenland it seems natural that European, as well as American, elements share in the orographic structure. According to Lauge Koch, who recently rearranged the orographic elements of Greenland, those of American origin partly include the nucleus of the country, *i. e.* the gneiss areas which make part of the Canadian Shield, and partly the Paleozoic sediments, which are offshoots from extensive layers in the Arctic Archipelago. The basalt formation, on the other hand, points towards Europe, being exactly continuous with the Tertiary basalt of which Iceland and the Faeroes consist, and which is also represented in Scotland and Ireland.

To geographers the relative ages and relationship of rocks are, however, merely of secondary importance. What in the first place determines the appearance of the land-forms is their structure and resistance, which is comparatively independent of their geological age. From this point of view the rocks of West Greenland may be comprised in the following summary:

I. Solid Rocks.

Massive or schistose structures	Gneiss, Chrystalline schists	Metamorphic and plutonic rocks
	Granite, Syenite, Nepheline-Syenite	
	Porphyry, Porphyrite	Volcanic rocks
Composite or bedded structures	Basalt and tuff	
	Sandstone	Sedimentary rocks
	Shale	

II. Loose Formations.

Stones and gravel	Rock *débris*, screes.
	Raised beaches.
	Erratic boulders.
Sand	Eskers.
	Dunes.
Clay and dust	Loess.
	Alluvial plains.
Composite formations	Till, drumlins.
	Moraines.
Organic formation: peat.	

Massive and Schistose Structures. Our first task is to investigate the resistance of the chief rocks and the influence exercised by their qualities on the relief of the surface. The greater part of the surface of West Greenland consists of gneiss, here and there with secondary layers of mica and hornblende schists. While monotonous as a whole, it varies both as regards colour and composition and strike, though in many places, at any rate in the central parts, the chief direction of the strike is east or north-east. Round Nordost Bay the gneiss forms almost horizontal bands. The resistance depends upon the character of the rock. Iron and hornblende gneisses are more apt to crumble than other varieties. In the Upernivik District, where grey and red gneiss alternate, the former, which is the harder rock, is seen to rise in the direction east-west as ridges comparatively rich in vegetation, above almost bare red masses. In the Julianehaab District there is gneiss weathering away so easily that the screes in some places form actual peninsulas projecting into the fiords.

Gneiss is apt to split along certain lines or joints which continue with

great regularity through the rock. These joints were made the subject of particular investigations by Kornerup, who was able to follow the same system over huge areas, as from Godhavn to the Frederikshaab Glacier, along which distance the strike did not vary more than 10°. Kornerup, beyond a doubt, exaggerated the importance of the joints in the development of land-forms; still, it is evident that they contributed considerably towards stamping the scenery with its peculiar character.

Everywhere in the gneiss area, but least in the central districts, dykes of diabase and granite occur, more rarely also gabbro, dolomite, and marble. The diabase, on an average, is more apt to crumble than the gneiss, and the dykes have frequently been transformed into ravines. In the Julianehaab District, where dykes of diabase are extremely common, many originally continuous islands are dissolved into islets, because the sea has penetrated into clefts due to former dykes. In a few places the intrusive rock has become metamorphosed into a dark amphibolitic rock which, for instance, round the mouth of South Strømfjord, is of such common occurrence in the light gneiss-granite that the latter at a distance assumes a banded appearance. The granite dykes are frequently of a pegmatitic character and have little power of resistance against weathering, while they have been fairly proof against glacial erosion; such dykes, therefore, stand out as hummocks above the surrounding rock.

Between gneiss and granite there are in many places quite gradual transitions. From the mouth of South Strømfjord to Sukkertoppen there is an area of gneiss-granite, a scenery of impressive beauty, because the glaciers and, consequently, all alpine features are developed to an exceptional degree, though on an average it is not higher than the gneiss mountains of the neighbouring districts.

A true granite is the Julianehaab granite in the region nearest Cape Farewell. It is light-grey and very resistant against the attacks of the climate, so that the weathering which has taken place since the ice age is minimal, and only a small quantity of talus covers the base of the mountains. This power of resistance is also expressed in the land-forms, the granite mountains on the east side of Julianehaab Bay being higher as well as more rugged than the gneiss and syenite regions. However, a granite area is not always *eo ipso* an elevated one. The north side of Julianehaab Bay, where the rock is exactly the same granite as that on the east side, is, on the contrary, comparatively low and rounded by the ice. There is reason to suppose that this is due to the fact that the Pleistocene ice cap in this place at different times has proceeded both from the north-west and from the north-east and, consequently, in the former case made part of the huge continuous sheet of inland ice, the eroding force of which must have been enormous. The east side of the bay was, however, only eroded by a small and, beyond a doubt, comparatively feeble offshoot from the

entire ice cap of the interior, for which reason the whole country, and more particularly the granite parts, are higher in this place.

The syenite, which in many places occurs in smaller quantities, is a rapidly disentegrating rock. The syenite hills behind the Frederikshaab Settlement bear the significant name of Raadne Fjælde (rotten mountains), and when ascending them one has in fact the feeling of sliding down one

Fig. 2. North shore of Tunugdliarfik Fiord, with Ilímaussaq in the rear. (Ussing). Remnants of volcanic sheets resting on plutonic rocks.

step for every second one advanced, because the loose *débris* is constantly sliding down underfoot. On the other hand, the greater number of steep sides and isolated peaks in the Upernivik District are said to consist of syenite or diorite.

In the Julianehaab and the adjoining regions of the Frederikshaab Districts various kinds of nepheline-syenite occur over comparatively small areas, penetrating through the upper layers as batholites, and constituting one of the most peculiar topographical types in Greenland. In a classical monograph Ussing accounted for the geology of this region. Itself not very resistant, but partly protected by superincumbent layers, the Ilímaussaq batholite stands out with snow-glittering peaks 1410 m above the fiord, and not far from it Igdlerfigssalik, attaining a height of 1725 m (cf. fig. 27). Huge masses of talus lie about the base of the mountains, and actual stone rivers, constantly fed by the enormous disintegration, glide imperceptibly down the less abrupt slopes. So rapid is the crumbling of the rock that

not even plants are permitted to take root, the mountains standing in their bald and unashamed nakedness, grimly contrasting with the sweet-smelling heath and the willow-clad valleys of the surrounding granite country (fig. 2).

The above-mentioned harder roof above the batholite consists of volcanic sheets (porphyry and porphyrite), which are greatly metamorphosed by contact and, in consequence, hardened. The non-metamorphosed parts were, beyond a doubt, less resistant and are now entirely removed by erosion.

Composite and Bedded Structures. The batholites with their pe-

Fig. 3. Sandstone cliffs near Igaliko. (Ussing).

culiar forms and complicated structure, as well as the volcanic sheets above them, only cover infinitesimal areas in the map of Greenland and, from a geographical point of view, suffer no comparison with the grand volcanic strata in the northern regions. The area occupied by the latter, which is particularly well known through the researches of K. J. V. Steenstrup, form the entire outer part of the coast land between Godhavn and Prøven or, in other words, the greater part of Disko and the peninsulas of Nûgssuaq, Svartenhuk, and Ingnerit with the neighbouring islands. However, there is hardly any doubt that still greater areas, in the west as well as in the north, at one time were covered by basalt, but that this rock has now been worn away by erosion.

The lowest strata of the basalt are, in several places, a very hard breccia which makes the shore stand out in wild and jagged outlines, with numerous small inlets, caves and isolated cliffs. Above this, up to 2000 m height, lie

regularly alternating layers of brownish black basalt and reddish tuff, each double layer representing an old volcanic eruption, during which the lava flowed out widely from the centre of eruption. The layers are rarely absolutely horizontal, but most frequently incline slightly to one side or another. Therefore, it is here comparatively easy to ascend the mountain, even though it is entirely inaccessible on all other sides. Neither basalt nor tuff are particularly resistant against weathering, but whereas the former has a columnar structure and is apt to split along vertical planes, the still softer layers of tuff form more evenly sloping ledges. Huge plateaux, broken by valleys and crowned by ice, isolated, mesa-like mountains towering in gigantic terraces or standing out like snow-clad Babylonian temple-pyramids

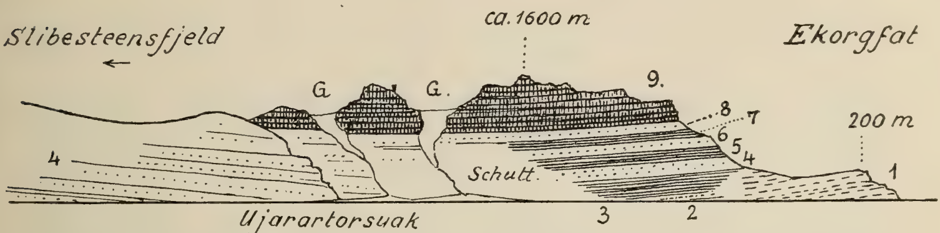

Fig. 4. Sketch of coast between Ikorfat and Slibestensfjeld, Nûgssuaq Peninsula. (Heim). G, Glacier. 1, gneiss. 2—8, sandstone and shale alternating. 9, basalt.

above fiords glittering in the rays of the sun, this is the indelible impression received from the basalt regions.

Precambrian rocks and, in the regions just mentioned, basalt characterize the Greenland scenery. What is otherwise found by way of rocks is chiefly of local interest. In the batholite area there is the so-called Igaliko sandstone, the remainder of a formerly widely extended formation which now only covers an area of 200 square kilometres. It is red, rather hard and traversed by dark dykes and sills, nearly horizontal and easily split into large square blocks, such as were used by the old Norse settlers as building material for the cathedral at Gardar. Owing to the peculiar properties of the rock a scenery arises, in which small plateaux and level grass-clad plains, broken up by vividly red, vertical walls, are the prevailing features, still more conspicuous because in the same region we find the wild, snow-clad batholites and rounded granite hills (fig. 3).

Of the greatest interest to geologists because of their splendid plant fossils, and important to the population because of their coal-beds, but rather secondary as elements of the surface, are the northern sediments, which either lie sheltered below the basalt (fig. 4), or, as in Upernivik Island, protected by steep gneiss walls. They consist of loose, light coloured sandstone and darker shales, all of which are soft and easily disintegrated. In the main they are only exposed in certain places on the coasts of Disko and Nûgssuaq Peninsula, where they form a gradually sloping, light base

below the murky walls of the basalt mountains. Hard basalt dykes here and there crop out through the strongly eroded sediments, as in the case of Rink's Obelisk at Atanikerdluk.

Layers of Loose Earth occur everywhere in West Greenland, but they play no great part in the scenery, as all loose material from pre-glacial times was worn away by the inland ice. However, the low interior country of the Holsteinsborg and Sukkertoppen Districts forms an extensive, partly

Fig. 5. Alluvial plain, surmounted by gneiss hills, between Sydost Bay and Arfersiorfik Fiord. (P. Harder).

till-covered area, where eskers are of not infrequent occurrence, and where also some low gravel hills have been described as drumlins. Many valleys throughout the country hold moraines of Pleistocene or more recent age. The Jacobshavn and Torssukátak iceberg banks, as well as the substratum of the large plain in front of the Frederikshaab Glacier, are of morainal composition. The Pleistocene inland ice has, further, scattered erratic boulders, frequently of huge dimensions, throughout the country; nowadays however it is as a rule necessary to ascend to some height in order to find other stones than those due to recent disintegration, as the level of the sea in post-glacial times was higher than it is to-day and to a very large extent washed away the stones deposited by the ice.

Elevated, post-glacial shore lines and terraces occur in many valleys where consequently the mountain slopes subside quite abruptly below the layers of earth in the bottom of the valley. So at Fiskenæs Fiord five ter-

races, up to a height of 101 m, have been counted one above the other. These terraces, though not significant to the scenery, are still so conspicuous that the native population as a rule denote their presence by attaching the name of *narssaq* (plain) to the lower one. Between Sydost Bay and the inner ramifications of Arfersiorfik Fiord, there are, on the other hand, really extensive plains of clay and sand, surmounted by scattered gneiss hills (fig. 5). These plains were examined by Ad. S. Jensen and Poul Harder. Similar formations also occur in other localities, as in the Holsteinsborg and Sukkertoppen Districts, but here they have not been studied in detail.

The sedimentation taking place in our own days will be mentioned in another context.

INTERNAL AGENCIES.

Movements in the Lithosphere. From the earth's interior a number of forces issued, which greatly contributed towards shaping the land-forms of Greenland. In some periods ("periods of revolution") these forces were stronger than in others; mountain chains were folded upwards, or portions of the earth's crust subsided through faults, or the lava of volcanoes flowed across the country. At other times these forces were at rest; in fact, it is probably only on account of its European affinities (manifested in the Tertiary lava eruptions) that Greenland has not been undisturbed since the Precambrian era, like the rest of the Canadian Shield. To-day it seems to be in the midst of a "period of evolution." Nevertheless it will be necessary to give a summary of the action of internal forces.

Most Precambrian formations have been subject to an intense folding, but this is not the case with any of the younger formations. On the other hand, faults undoubtedly played a considerably greater part, and it is, for instance, owing to a displacement that the Igaliko sandstone and the volcanic sheets in the Julianehaab District have been preserved against destruction (fig. 6). This area has subsided between two faults striking NE—SW and therefore has not been worn away by erosion. It is also possible that both sediments and basalt farther north have been preserved in consequence of a throw which, by some geologists, is supposed to pass across Svartenhuk Peninsula, Upernivik Island and Nûgssuaq Peninsula, and continued in the sound between Disko and Arveprinsens Island.

In connection with the displacements, mention should be made of the earthquakes which, however, have never been of a destructive nature, and which are also of far rarer occurrence in West Greenland than in the region round Angmagssalik on the east coast. Within the period 1903—13 three faint shocks were recorded in West Greenland, and besides there are some chance observations from an older period. The Holsteinsborg and Godthaab Districts seem to be the most unsettled parts, but upon the

whole West Greenland must be said to have experienced very few earthquakes.

Various, now greatly elevated, pre-glacial sediments show that the coast in a remote geological past has been subject to extensive changes of level. At the end of the ice age the level of the country was lower than at the present time, and this sinking was continued, even in post-glacial times. Since then the coast has once more undergone an uplift, least however towards the south, where the upper marine limit is indicated at 50 m round Julianehaab, whereas on Svartenhuk Peninsula it lies about 150 m above the present sea level. To-day the coast is slowly subsiding. Numerous old ringbolts are now submerged, and the islet on which the oil refinery of

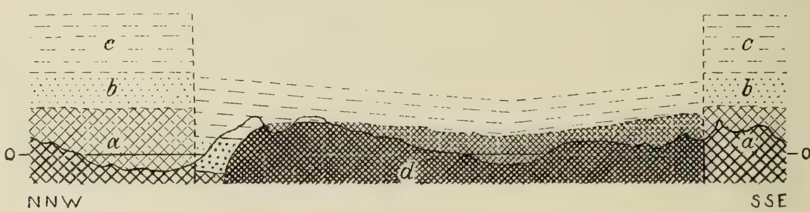

Fig. 6. Reconstructed cross-section of Ilímaussaq batholite. (Ussing).
a, granite. b, sandstone. c, volcanic sheets. d, plutonic rocks. The position of the section is indicated on the sketch map fig. 9.

Egedesminde was erected is now divided by a channel which did not exist in 1799. The rate of subsidence, however, at most amounts to one or two metres in a century. In order fully to estimate the importance of these littoral movements it should be borne in mind that they not only determine the absolute height of the country, but also change the base level of erosion.

Warm Springs. At the present time there is no volcanic activity in Greenland, but traces of a former unrest have not entirely disappeared. The greater number of hot springs are to be considered as being such faint after-effects, in several places creating diminutive oases, where plants and invertebrates from more southerly regions are able to find a living. A spring of this kind is in the Eskimo language called *ũnartoq* (the warm).

The warm springs of the Julianehaab District were known by the old Norse settlers, who used them for bathing. They are situated on a low neck covered by till, connecting the high granite masses in the southern part of the small Ũnartoq Island with a lower granite hill towards the north, and consist of three quite shallow basins, the largest of which only measures 8 m in diameter. Here warm water and air-bubbles rise quite slowly from the bottom. The temperatures of the various basins in 1919 ranged between 32° and 37° C. The water is faintly saline (0.965 grams of salt in 1000 grams of water) which is supposed to be due to the admixture of infiltrated sea water.

Much farther north, in the Egedesminde District, there are a few other

springs in the Precambrian rocks, *viz.* in the gneiss island Sarqardlît. It is true that the temperature of the water is only 5° or 6° C., but it should be borne in mind that the mean annual temperature in this place is slightly less than —6° C. We here approach the basalt region of Disko which, in respect of warm springs, is unparalleled in Greenland, simply because the volcanic activity in these regions is nearest to our own day. Scattered over large areas of the island, but notably on the south coast and in the interior parts of Disko Fiord, these springs occur, their temperature, however, being very moderate, ranging between 2° and 6° C. and only once in a while attaining about 18° C. Still, this is sufficient to prevent the formation of solid ice off the coast near the outflow of the larger springs. The water is so pure that there is no deposit of sinter, except in the case of a single spring where gypsum is deposited.

EXTERNAL AGENCIES.

Cycles of Erosion and Changes of Climate. It was emphasized above that the present is never understood except against the background of the past, and the importance of historic perspective in the interpretation of the scenery is at least as important in the case of external as in that of internal agents. An upheaval or a subsidence of the country involves a new cycle of erosion, and the same is more or less true of an essential change of climate. The changing climates of former geological periods have not passed over Greenland without leaving their traces, and the modelling by erosion to which it has been subject during the geological present is infinitesimal as compared with the immense sculpturing of the past.

Even to-day the interior of Greenland is a tangible picture of the ice age, but within the Pleistocene epoch the whole of the coast land was also covered by the inland ice. The layers of loose earth which had formed before that time were all swept away by the ice, which denuded the rocks down to their solid naked core, and everywhere in the land-forms we now meet the traces of the ice, from the humble, glacier-ground *roches moutonnées* of the island belt to the fretted comb-ridges rising above the eternal snow of the mountains. The inland ice itself, at any rate in the extreme south of Greenland, may be considered a huge relict, in point of fact as strongly discordant with present conditions as the lower course of the Nile with the surrounding desert.

But this must not make us forget that although the ice age, in great as in small matters, has stamped the country with its unmistakable character, the land-forms, as first laid down, lose themselves in the darkness of very far removed times. We are carried back to those days when the Tertiary formations were deposited, when the country was covered with large forests of magnolia, laurel, chestnut and oak, and the climate was as in southern Central Europe—or to the still dimmer Cretaceous period, when tempera-

tures most nearly corresponding with those of southern U. S. A. called forth a sub-tropical vegetation, with trees related to the bread-fruit trees, tulip trees, and so-called sago palms of to-day. The aspect of the land-forms in those days may only be dimly grasped, but there is no doubt that the action of glaciers at that time was at most insignificant and that humid erosion is chiefly responsible for the modelling of the surface in those ages.[1]

Weathering. The outlines of the physiognomy of Greenland are principally due to the past, but whoever sets foot in the country is at once confronted with evidences of the continuation of this activity, seeing that a constant destruction is going on, slowly but incessantly, at the same time as a process of deposition takes place in other localities. The latter, however, for the greater part takes place in the sea, and the exogene agencies are therefore mainly destructive.

The inclement and raw climate, in particular along the outer coast line, prepares the way for a disintegration and decomposition so comprehensive that over great areas it is impossible to find glacial striæ in the rock. It is evident that the joints to a very large extent contribute towards the destruction of the rocks, and in many cases it is impossible to differentiate between weathering and splitting. Those unfamiliar with the Arctic do not always fully realize the fact that the Polar regions are in reality subject to violent and sudden changes of temperature. When the warm foehn winds blow during the winter, the temperature in the course of a few hours may rise from —30° to + 10° C., and in the summer a black rock may frequently be heated to 40° or 50° C., while the air only registers 8° or 10° C. Such differences of temperature must naturally have a destructive effect on the rocks, in particular when they consist of variously coloured minerals.

The effects of temperature are further heightened by water oozing down and alternately freezing and thawing in the fine pores of the rocks. Therefore, the zone round a melting snow drift, but more particularly the marginal crevasse (*Bergschrund*) between the glacier and the valley side is subject to an excessive nivation. By the mechanical weathering the rock is split into angular flakes and blocks, and so in the Julianehaab granite there often arise tall, almost vertical, smooth and naked walls, frequently several hundred metres in height. Wherever there is a fairly luxuriant vegetation, the plants naturally yield some protection against crumbling.

Sometimes a peculiar form of disintegration occurs within the Precambrian area, *viz.* an exfoliation of large crusts, sometimes only a few milli-

[1] It goes without saying that less, or rather nothing whatsoever, is known of the climate of Greenland within still earlier periods. As far as the *east* coast is concerned Otto Nordenskjöld emphasized the occurrence of immense, intensely red layers in the pre-jurassic rocks, which may suggest the formation of laterite, and so a warm climate.

metres in thickness. This form seems more particularly to belong to rocks, polished by the former ice cover.

Simultaneously with the disintegration the chemical decomposition proceeds. The syenite breaks into sharp felspar gravel, when the hornblende contained in it decomposes, whereas the basalt is transformed into a clay-like substance, and gneiss becomes gravel or coarse sand which, when subject to oxidation, assumes a coating of brown rust; but on the other hand it is not all kinds of rock that are equally susceptible to this decomposition, as it seems to be controlled by the amount of magnetite and pyrite granulæ. The consequence is that in certain places there are holes and shallow pits eaten into the rock. This is, for instance, seen behind the Ũmánaq Settlement, where a greyish gneiss occurs, traversed by white quartz veins. In those naked sides which are not highly polished by the ice, there are holes like swallows' nests in a dyke and, when the partition between them disappears, several holes coalesce into irregular cavities. A reddish gneiss in the neighbourhood disintegrates in a different manner, being parted into angular fragments. Similar forms of decomposition also seem to occur in other parts of West Greenland. In some cases the surface is furrowed by a network of narrow channels, divided by sharp or slightly rounded ridges to such an extent that it has been compared with the *Karrenfelder* of the Karst regions.

The most peculiar form of decomposition, however, occurs in the curious steppe-like area described by J. A. D. Jensen and, later on, by Otto Nordenskjöld from the interiors of the Holsteinsborg and Sukkertoppen Districts. Here, where the climate is far more dry than at the outer coast, stone blocks are met with, the shape of which would be less striking in Sahara than in Greenland; they are full of cup-shaped cavities, as it were contorted and lobed and sometimes even perforated. While Eolian erosion may have contributed towards this result, it seems as if the origin of these stones is chiefly due to chemical decomposition under the influence of disengaged salts. It is a well-known fact that in these regions sulphates and chlorides of sodium, magnesium, and potassium will effloresce, being elutriation products from the decomposition of the rock.

Denudation occurs together with weathering, the *débris* gradually making its way down into the valleys. As regards the large blocks it mostly takes place in huge screes, forming a cone of talus at the mountain base (fig. 7). The spring season with its interchange of frost and thaw is the time of the rock slides, when it is wiser not to move about below steep and crumbling mountain sides. On a former occasion mention was also made of the peculiar solifluction within the areas of the less resistant nepheline-syenites, from where Ussing described actual stone rivers, sometimes as much as several kilometres in width, with stones ranging in size between a hazel and a walnut and sliding quite slowly down the even slopes. Though

presumably to a lesser degree, solifluction is known from several other West Greenland localities, *inter alia* from the basalt area.

In this connection it should be mentioned that, in the loose layers of earth of West Greenland as well as of other Polar countries, the so-called *rutmark* ("chequered soil") occurs. It has not been possible to give any quite satisfactory explanation of this phenomenon, which consists of a regular arrangement of gravel and earth in polygons or striæ; but it is

Fig. 7. Talus at the foot of Qingaq near Holsteinsborg. (Th. N. Krabbe).

probable that solifluction and the constant interchange of frost and thaw have played a certain part.

Running Water, it is true, can only have any effect during the summer, but then its action is all the more powerful, because rock and ice ground do not permit of the water sinking into the soil. Since the ice age the glacier valleys in many places have been metamorphosed by running water, nor are cases lacking where the valley is the exclusive product of post-glacial river erosion. This must generally be supposed to be a linear erosion. In the narrow coast fringe of Greenland which is furthermore, by fiords and sounds, cut up into a maze of islands and peninsulas, great river systems cannot develop; add to this that the present cycle of erosion geologically only dates from yesterday, and it is obvious that planar erosion (Supan's *flächenhafte Destruktion*) as carried out by the rivers when excavating their beds horizontally, cannot be expected except in special cases.

During the ice age water action was quite exceptional, though evidence

of the action of glacial rivers at that time is supplied by numerous giants' kettles, formed in places where the melting water from the surface of the ice rushed down through a fissure in the glacier. Corresponding pits (*Sölle*) have been observed in sand near the present margin of the inland ice. Of far greater importance was, beyond a doubt, the humid erosion within pre-glacial times. There is nothing to prevent the supposition that there were huge river systems in Greenland, the erosive power of which far surpassed that of the present rivers. In a following paragraph we shall discuss the occurrence of old peneplanes in West Greenland, but at this early stage it may be mentioned that they seem to be essentially of humid origin.

Deposits due to running water are particularly formed at the heads of certain large incisions: North and South Strømfiord, North and South Isortoq, Kobbermine Bay, etc. where melting water from the inland ice will create large glacifluvial plains from its outwash. In a "clayfiord" of this kind (Greenlandic: *isortoq*) the glacier formed by the inland ice is stationary, but all stages of fiords occur, from such where clay is only deposited on the bottom, others where the river meanders in innumerable channels across a level, naked plain, and again others where the plain has already undergone an uplift and the river, consequently, has cut down into a terrace covered with vegetation. In the interiors of these fiords travellers should guard against going aground with falling waters; for if this happens, the boat will gradually be caught in the mud, so that boat and cargo will be hopelessly lost, and only in very few cases will the crew manage to get ashore. J. A. D. Jensen states that the stay at North Isortoq was almost unbearable. A thick cloud of dust, which the least breath of air was able to raise, was constantly hovering over the broad river and its banks, and hills and plants presented a grey and bleak appearance. The water samples which were taken in this locality, on June 18th, proved to contain a suspended material of more than 9000 grammes in 1 cubic metre of water, or nearly four times the average amount carried by the Indus.

A similar formation is the great plain off Frederikshaab Glacier, but this plain, as distinguished from the others, extends to the open Davis Strait, merely sheltered by some skerries which are now half buried by the deposits. Above the old moraine which forms the bottom, clay and sand are constantly deposited, and from these the plain derived the name of Sioraq, exactly corresponding to the *sandr* of the Icelanders. These deposits are carried along by the glacial rivers so that the sea far out is milky with outwashed clay particles, and when at ebb tide the plain is laid dry, the latter are left like a fine layer of mud.

The Action of the Ice in our days is only a faint echo of the gigantic work done by the Pleistocene inland ice, at the time when the entire coast land, with the exception of a few peaks, was buried below its masses. Traces of glaciation were found in Nordost Bay up to 1600 m, slightly north

of the Frederikshaab Glacier up to 1100 m, and in the Julianehaab District up to 1000 m. As it will appear from the following paragraph on the morphology of land-forms, it is here necessary to distinguish sharply between the planar erosion which took place below the inland ice itself and the linear destruction due to single glaciers, whether local or lobes from the inland ice.

The Pleistocene glaciation has stamped the coast land of Greenland for interminable ages, and even if we should not undervalue the glacial erosion of to-day, it must be borne in mind that at present it keeps within certain limits. It is in the uplands, in the cirques where *névés* accumulate, as well as in the glacier valleys protruding from the mountains into the lower foreland, that we must look for the glacial erosion of the present day. In this particular Arctic West Greenland does not deviate materially from the Alps or from any other mountainous country within temperate climates. The difference is only that the snow limit, and so also the Alpine zone, extends to lower levels in the Arctic.

In a former paragraph mention was made of the glacial deposits from the ice age, and at the same time it was emphasized that, compared with the other formations in Greenland, they are very insignificant. This of course, to a still higher degree, applies to the recent moraines, which only act locally upon the general character of the scenery.

Actions of the Wind. The importance of humid and glacial erosion to West Greenland is striking and not very surprising. It is far more interesting that in West Greenland there are regions fairly large in extent, where the agency of the wind plays a considerable part. We are naturally not thinking of the localities here and there, where dunes are formed owing to special conditions, but of the above-mentioned "Polar steppe" immediately in front of the inland ice in the Holsteinsborg and Sukkertoppen Districts. Unfortunately the knowledge of this region is still insufficient. The climate is there relatively dry, lakes are frequent, but often without outlets, and the rivers from the inland ice flow in deeply excavated valleys without having any great influence on the drainage. In this low and open country, where humid erosion thus only makes itself faintly felt, and where the vegetation is often sparse, the wind in return has free play, which is, *inter alia*, testified by numerous mushroom-shaped boulders.

Here also a peculiar eolian deposition is taking place. When the volumes of the glacial rivers decrease, large stretches, bare of vegetation and covered by fine clay dust, are exposed in the valleys along the banks of the river. Like the glacifluvial plains in the clay fiords the dust is set into motion by the faintest breeze, and it is carried by the wind far over the surrounding plain. Here its progress is checked by the vegetation, and a deposit is formed which, according to the samples examined by Otto Nordenskjöld, in composition and size of grains greatly resembles loess, though without the con-

sistency of normal loess. It is not necessary to emphasize the importance of this result towards understanding the European and North American loess formations, which are supposed to originate in the regions near the margin of the Pleistocene ice sheet.

What the **Marine Action** was like in earlier periods, we have no idea, but at the present time it is naturally in force all along the coast. It goes without saying that the outer coast is more exposed to the attacks of the

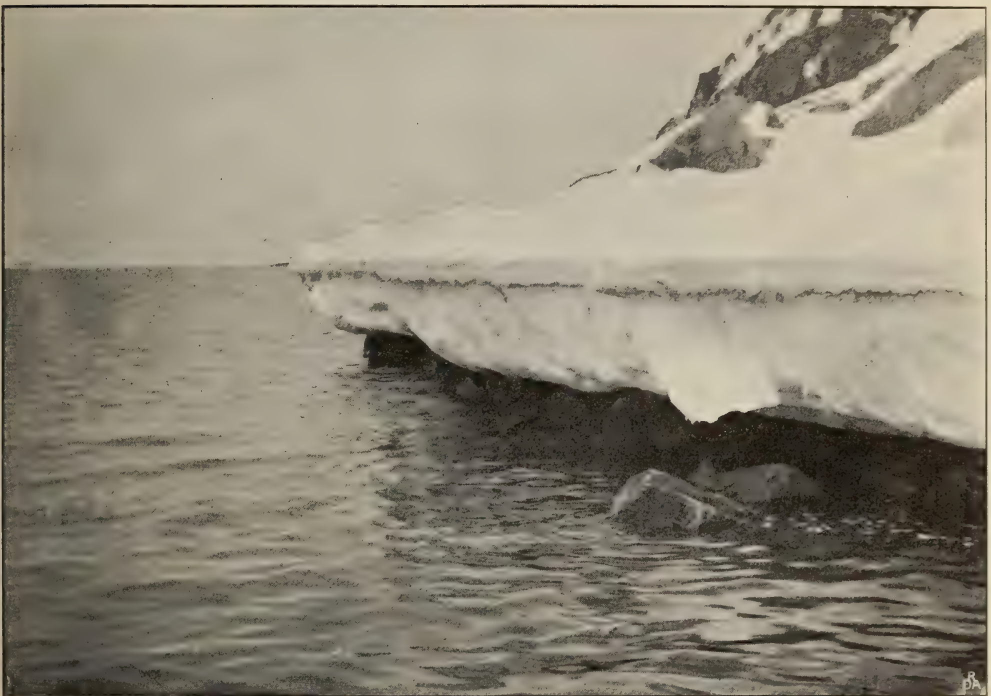

Fig. 8. Ice-foot at Egedesminde, May 13th. (C. Wagner).

waves than fiords and inlets, and as the sea is sufficiently deep to permit of the waves bearing in upon it almost with all their strength, it gradually accomplishes a very considerable abrasion. On the other hand, there are long periods of the year along the northern part of the shore, during which the sea cannot act in this capacity owing to the winter ice.

In the Arctic there is, however, a special factor working together with the destructive agency of the waves, inasmuch as the sea ice plays a part which should not be undervalued. The drift ice is hardly to be considered in this connection, but all the more the peculiar type of erosion which by Nansen is called "shore erosion by frost." The ice fringe or ice-foot, which forms at highwater mark, remains until far into the summer, long after the floe has broken up and drifted away (fig. 8). The constant thaw and frost, at the line where ice-foot and solid rock meet, causes a nivation resembling

the action of the *névé* against the sides of a cirque. Nansen is even of opinion that this explains the formation of the so-called coast platform, which is to be found in several places along West Greenland, though less pronounced than in Norway. As maintained by Otto Nordenskjöld the Pleistocene shelf ice may also have acted in the same direction.

In West Greenland of to-day marine deposits in the proper sense of the word are not laid down in such quantities as directly to influence the scenery, and towards this the subsidence of the coast naturally contributes. Still, lagoons occur here and there along the north-east coast of Disko.

MORPHOLOGY OF LAND-FORMS

SURFACE RELIEF.

Altitudes: Central Greenland Depression. After having given the above summary, partly of the material composing the surface, partly of the agencies which have been brought to bear upon the rocks, we will at some length discuss the individual land-forms and their origin.

West Greenland is a mountainous country, although of moderate heights. Most peaks of any importance are between 1200 and 1600 m high, and only few exceed 2000 m. Such are only found in two localities, the Julianehaab District and round Nordost Bay. On the great peninsula south of Tasermiut and Lindenow Fiords, only 75 km north of Cape Farewell and about midway between the west and the east coast, rises the highest peak of West Greenland, Sulugssugutâ (2240 m, or higher than Mt. Pilatus in Switzerland) in the midst of splendid Alpine scenery. The greatest height, outside the Julianehaab District, is attained by the glacier-covered peninsula Akuliaruseq (2150 m), south of Karrat Icefiord in Nordost Bay. The basalt region is not much inferior in height to the Precambrian area, and on Nûgssuaq Peninsula there are peaks of about 2000 m, as Qilertínguaq (1960 m) which is not even the highest.

The actual mountains are more or less negligible when compared with the Alps of Switzerland, but in spite of this the Greenland scenery can hold its own against any other. Glittering fiords with majestic icebergs, promontory upon promontory standing softly silhouetted against the pale gold of the midnight sun, here and there a jagged crest towering above the glowing snowfields of the peak—a thousand features melting into a mute symphony of purity and a peace that passes all understanding . . .

However, one cannot help being struck by the peculiarity that within the Precambrian formations there are two regions in which the height increases. In an interesting and suggestive treatise Lauge Koch, whose attention was first attracted by this fact, tries to sum up the distribution

of the heights, and on the strength of this summary he is led to assume the presence of a large depression across Central Greenland.

All known altitudes within the Precambrian and plutonic rocks of West Greenland were projected at right angles on a line drawn parallel with the coast, and by connecting the highest points he laid down the maximum heights of the individual regions. The diagram goes to show that the heights, generally speaking, fall from Cape Farewell to Disko Bay, north of which they suddenly rise violently, falling once more towards the north, until in Kane Basin they are submerged in the sea.

The few deviations from this general rule, as shown by the diagram, are by Koch explained in various ways. When the Frederikshaab District seems particularly low, it is according to him because only very few and unsatisfactory surveys are at hand from these parts[1]. In the Holsteinsborg and Upernivik Districts, on the other hand, a number of peaks without apparent reason attain quite exceptional heights, but this is supposed to bear upon petrographical characteristics, *viz.* the respective occurrence of iron gneiss and of younger, igneous rocks such as granite, syenite and diorite, and it is pointed out that in the interior of the Holsteinsborg District we actually come across the low relief which one would expect. Although the considerable heights in the Holsteinsborg outer land must really be supposed to be due to special causes, it is, however, doubtful whether the iron gneiss is responsible, for this rock is very little resistant, and the common grey gneiss within the same regions makes just as high mountains. This objection, however, naturally only touches the periphery of the hypothesis.

The profile drawn by Lauge Koch of the east coast of Greenland shows altitudes which correspond entirely with those of the west coast, and the few observations at hand as regards the height of the inland ice may, perhaps, point in the same direction. Consequently, there is reason to suppose that a depression extends right across Greenland, in the zone where the Tertiary basalt eruptions took place and in some way or other undoubtedly connected with the latter. According to Koch "it is not inconceivable that the displacement may have taken place along a single fissure or a very narrow fracture zone, without the gneiss planes being broken up into smaller areas." (Journ. of Geol. XXXI, p. 64). The matter is, however, hardly so simple as all that; certain facts seem to suggest the occurrence of several faults in this very region. There is no doubt that a detailed stratigraphic and tectonic investigation, in connection with an exact topographic mapping of these parts where Precambrian, Cretaceous, and Tertiary formations occur together, would not only be of great value to geol-

[1] My personal impression which, it is true, dates several years back, agrees with the hypothesis of Koch in so far as I did not find this district strikingly low.

ogists, but also contribute considerably towards dispelling the darkness which prevents the understanding of the West Greenland scenery.

Tectonic Forms. Not only the altitude of West Greenland as a whole, but perhaps also individual land-forms have, in several cases, been influenced by the tectonics of the country. Such forms might first and foremost be expected in the basalt area, but at the present stage of our knowledge their occurrence still remains uncertain. The relief, it is true, is greatly influenced by the stratification, but only minute investigations, which are still lacking, can show to what extent the plateaux represent the surface of the ancient lava-flows. In some cases at least, the surface is not the original one, being on the contrary due to erosion. To this question we shall return presently.

As regards the importance of the faults to the relief of West Greenland, it must constantly be borne in mind that valleys and fiords are never directly due to dislocations, but that we are only dealing with erosional forms, the trend of which may be controlled by faults.

It is, however, at the present time impossible to say anything for certain as to the influence of faults. In former times, when both geologists and geographers were less apt to acknowledge the force of erosion, and especially of glacial erosion, it was common to ascribe to faults an essential share in the development of land-forms. A. E. Nordenskiöld, K. J. V. Steenstrup, and E. von Drygalski all expressed themselves in favour of the view that the directions of the West Greenland fiords were determined by dislocations, and if this view were the correct one, it was also to be expected that many valleys were identified with faults, as the fiords are merely overdeepened, pre-glacial valleys.

Nevertheless it is very doubtful whether displacements played such a decisive part in the modelling of the country as supposed by these writers. Only in a few cases have undoubted faults been proved in Greenland, though, on the other hand, it must be admitted that in an area, which in the main is Precambrian, a thorough investigation must be undertaken before old displacements can be proved. As mentioned above, the region round the Ilímaussaq and Igaliko batholites is on the north and south bounded by throws. Of these the southern one chiefly passes overland, but is of no geographical significance, as the boundary is obliterated by intrusive rocks. Still, it is possible that a small river running to the east side of Igaliko Fiord originally followed the fault and now has an epigenetic course. The northern fault coincides with the North Sermilik of Julianehaab, so there is naturally a possibility that in this locality the fault may have given rise to the formation of an erosional valley and, subsequently, of the fiord (fig. 9).

The area where traces of faults and throws may notably be expected to have influenced the scenery are the regions round Disko and Nordost

Bay, but hardly anything is known as to whether they actually do occur. The presumed fault right across the Nûgssuaq Peninsula seems to be characterized by a depression through which run the small rivers Kûk and Kûgssuaq, but otherwise we can only refer to certain features in the configuration and relief of the country, as pointing in the direction of faults. This does not only apply to the Vaigat, as was already pointed out by K. J. V. Steenstrup, but presumably also to the longitudinal valley traversing the Nûgssuaq Peninsula throughout its length, and supposed to run almost parallel with the Vaigat. This valley which seems so curiously irrelevant has not been made subject to investigation. The Uvkusigssat Fiord behind Svartenhuk Peninsula, which passes nearly north-south and runs parallel with the inland ice, as well as the Umîarfik Fiord farther west, are clearly epigenetic, but judging by their direction it is difficult to explain them as mere erosional formations, and this view is further strengthened by the fact that the Uvkusigssat Fiord lies in the exact continuation of the presumed north-south fault across the Nûgssuaq Peninsula and through the sound between Disko and Arveprinsens Island.

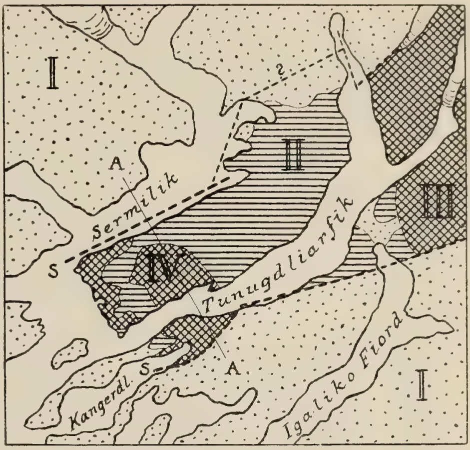

Fig. 9. Sketch map of country around Julianehaab, showing distribution of main faults (ss). (Ussing).

I. Granite. II. Red sandstone and volcanic sheets. III. Igaliko batholite. IV. Ilímaussaq batholite. A-A, line of section represented in fig. 6.

Sculptural Forms: Bedded and Composite Structures. Although the destructive forces are the same everywhere in Greenland, it is most expedient, owing to the different character of the rocks, to treat the various formations separately. The present cycle of erosion has left its strongest impression on the soft sandstones and shales. From Nordost Bay it is seen how the water courses have drawn a system of young, V-shaped valleys in the sediments at the base of the Nûgssuaq Peninsula and dissolved the surface into a number of ridges which have almost reached a mature stage. Seen at a distance their texture at times appears so fine as to suggest the "bad lands" type. When following one of these valleys from the shore, we are confronted with the curious fact that the valley increases in width upwards; this should presumably be explained on the strength of the post-glacial uplift of the country.

In the somewhat hard Igaliko sandstone traces of recent erosion seem less pronounced, whereas the Pleistocene glaciation has given rise to great

transverse depressions across the peninsulas from fiord to fiord; at any rate the narrow and low Igalikò isthmus makes an important portage for the native population, their principal sealing taking place in the neighbouring fiord.

As compared with the Cretaceous and Tertiary sediments the basalt is far less influenced by recent erosion. The contrast is striking between the low, light-coloured and greatly broken forelands and above them the high, steep and gloomy basalt plateaux which in the north-easterly part

Fig. 10. View from Qaersuarssuk, Nûgssuaq Peninsula. (Heim).
Basalt mountains rising above strongly eroded, sedimentary deposits. In front Pleistocene moraine forming cliff to the left.

of Disko rise to 17—1800 m, in the Nûgssuaq Peninsula even to 2000 m, while in Svartenhuk Peninsula they hardly exceed 1600 m (fig. 10). Chamberlin summarizes his view of the land-forms of Disko as follows: "The topography plainly indicates an ancient process of levelling, with a base plane some 2000 feet higher than the present. It also indicates that this did not reach completion, and that a very long interval of greater elevation followed, during which a lower plain, now near the sea level, was partly developed at the expense of the older one. In this the fiords and deeper channels were cut." (Journ. of Geol. II p. 770). Somebody has said that hypothesis is the salt of science, but it seems to me that in this case Chamberlin has seasoned his statements just a little too much. We look in vain for any discussion of the very meagre facts upon which this far-reaching hypothesis is founded; practically there is no argumentation at all, and Chamberlin's stay on Disko was so short that he can hardly have seen very much of the country. Still it is easily proved, for instance slightly west of Niaqornat in Nordost Bay, that in some cases the surface of the basalt area is really due to erosion,

for here the plateau slopes gently towards the east, whereas the dip of the basalt layers is in the opposite direction. Whether this should be ascribed to local conditions, or whether it is a general feature remains, however, an open question, as there is also another possibility to be taken into account. It seems likely that the basalt layers have essentially influenced the formation of the plateaux, in the same way as the intermediate tuff layers have given rise to denudation terraces. The possibility is, therefore, that the surface of the plateaux in a general way corresponds to the ancient lava flows. To be able to say anything definite as to this problem an extensive investigation of these regions should be made, and especially as there is also some evidence that important displacements have taken place here (cf. p. 444).

The rounded, soft land-forms which are due to the Pleistocene glaciation are not much in evidence in these localities, but on the other hand, there are in the higher parts distinct traces of local glacial erosion. Wherever the plateaux stand out above the snow line they are crowned by ice, and in many places glorious cirques have transformed the mountain peaks into gigantic ice-filled bowls. The aspect of the north side of Disko is in certain places almost Alpine, the mature cirques having eaten into the rock, until the partitions between them have dwindled down to sharp comb-ridges. From Ũmánaq a couple of huge cirques are seen below the Qilertínguaq Mountain on the Nûgssuaq Peninsula, and these cirques are divided by mature comb-ridges, the tops of which pass into the sharply defined horn from which the mountain derives its significant Eskimo name, i. e. the little hair-knot.

The great valleys of the basalt area are overdeepened by glaciers, and the transverse sections are consequently U-shaped; their upper parts are frequently closed by living glaciers unless, as is sometimes the case on Disko, they cut right across the country, from shore to shore. The bottoms of the valleys are filled with moraines, which in southern Disko are old and densely covered by vegetation, whereas in the northern part of the island they have not become bare of ice until at a much later period and, therefore, still have a very sparse vegetation. As the resistance of basalt against erosion, though greater than that of the sediments, is comparatively small, the period after the ice age has been sufficiently long for the rivers to leave their stamp on the smaller valleys, which are narrow, have V-shaped transverse sections and evidently are still in a juvenile stage.

Sculptural Forms: Massive and Schistose Structures. In the primitive rocks of West Greenland the ancient folding chains formed in Precambrian times have long been absent, and in the main we have to look towards erosion for the explanation of present land-forms. Few localities in West Greenland yield such ample opportunity for studying this fact as Nordost Bay. We are here in the midst of scenery where the beauty

of Greenland culminates in a majestic pæan of sun and ice and fiord, of pointed towers and spires as of gigantic Gothic cathedrals, and heavy mountain masses with restful lines, which in their turn, at the head of the Ũmánaq Fiord, where the gneiss is supplanted by mica schists, give way to more rounded forms. If we want a distinct proof of the strength of erosion,

Fig. 11. North side of Storö, Nordost Bay. (K. J. V. Steenstrup).

we only need consider the island of Storø (Sagdliaruseq) which rises right opposite to the Ũmánaq Settlement like a 1300 m high, synclinal block (figs. 11—12, cf. fig. 32), and the same holds good of the only slightly lower Akuliaruserssuaq Peninsula; in both places enormous masses of rock must have disappeared in the course of time. Otherwise the gneiss bands in this

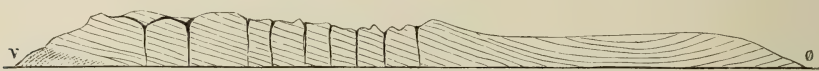

Fig. 12. South side of Storö, Nordost Bay. (K. J. V. Steenstrup).

region are approximately horizontal, and this is hardly without some bearing upon the plateau formation.

The Alpine forms, the rounded mountains, and the plateaux met with in Nordost Bay are all more or less typical elements of West Greenland scenery. As was to be expected, the plateaux are in other parts far less predominant than in the basalt region where they are probably partly dependent upon the character of the rock, but, on the other hand, they are not exactly rare outside Nordost Bay. The traveller who in the central parts of West Greenland leaves the outer coast and enters one of the long fiords will gradually see the valleys decreasing in number, while the mountains become more massive, until at last they form typical, faintly rolling plateaux which at heights of 1000 or 2000 m seem to slope slightly in the direction of the sea and frequently are covered by glaciers. In the Egedesminde District, where the altitudes are considerably lower, the country south of Arfersiorfik Fiord is seen to rise as a steep and grim wall up to a height of 100 m, above which the surface proper of the country extends as a rolling plain, where only single hills attain 500 m (cf. fig. 30). The easterly Holsteinsborg and the north-easterly Sukkertoppen Districts form a similar open and hilly country.

In the typical West Greenland scenery plateaux and hills are, however, far less common than evenly rounded mountains, mostly about 1000 or 1200 m in height, and only exceptionally an isolated remainder of the plateau is left among them as a kind of embryonic mountain (fig. 13). The transition between the two land-forms is so gradual that in some

localities, as, for instance, round Upernivik, it is doubtful with which of the latter the country should be classed. Here and there a single peak stands out, in apparent irrelevancy, above the uniform domes, and there is reason to believe that a peak of this kind will, as a rule, prove to consist of a harder substance which has been more able to resist destruction than the surrounding rock. Such peaks, generally known to geographers as "monadnocks," are Kællingehætten (i. e. the woman's hood) at Holsteinsborg and

Fig. 13. Rounded hills at Amerdloq Fiord, seen from Sarfánguaq. (Cruise of the "Fylla").

the 1125 m high Finnefjæld or Sulugssugut (i. e. the dorsal fin) near Sukkertoppen[1].

Recent weathering and water erosion have moulded many details in this rounded relief, and the dip of the gneiss bands has frequently influenced the land-forms; they often slope gradually in the direction of the dip, whereas their outcrops, on the other side, form steep and strongly crumbling slopes. The great forming agency was, however, the ice. In the main the rôle played by it is evident. It is the Pleistocene inland ice which, when burying the whole of the coast land, wore off the sharp angles, smoothed the contours, and drew the soft rounded lines. In particular off the larger fiords the small islands are frequently shaped like typical *roches moutonnées* with a gradually sloping side towards the motion of the ice and a steeper leeside.

Here and there, in the midst of these rounded land-forms, but most

[1] The latter should not be confused with the formerly mentioned, highest mountain of West Greenland, which bears almost the same name.

frequently at some distance from the outer coast, a mountain knoll may rise above its surroundings, to such a height that it can hardly have been covered by the inland ice, but must have protruded like a nunataq. It is frequently either covered by a glacier, or at any rate by its rugged forms suggests a former local glaciation, forming in this way the Alpine element of the country.

As the beacons of Godthaab the two mountains Sadlen (1210 m) and

Fig. 14. Hjortetakken near Godthaab. (Th. N. Krabbe).

Hjortetakken (1180 m) are visible far out at sea; their names, signifying the "saddle" and the "antlers" respectively, refer to the huge cirques of the tops (fig. 14). The cirque of Sadlen is enclosed by fretted comb-ridges, whereas Hjortetakken stands out as a tall, wildly shaped, but quite short crest, and a lower, rounded and highly ice-polished horn; the latter fact may indicate that the cirque formation, in this locality, is older than the last great glaciation. Farther south, near the mouth of Arsuk Fiord, Kûngnait (1395 m) presents similar Alpine forms.

As far as these mountains are concerned, it is the linear erosion of local glaciers and not the Pleistocene inland ice which has thus been the shaping agency. But apart from this the pinnacles and the comb-ridges have been subject to an enormous process of weathering, which has further contributed towards the bold and jagged forms. In exceptional cases local glaciers have not been able to form at all, for the snow is always swept away from the top, and if the sides are particularly steep there is therefore no opportun-

ity for the formation of *névés*. In that case the modelling of the peak is essentially a result of weathering. An excellent case in point is Redekammen (i. e. the comb) or Kitdlavât in the Julianehaab District. The latter is part of the granite wall bounding the Ilímaussaq batholite on the south, and, impressively steep, it now leaps upwards above the greatly eroded nepheline-syenite area as a 1190 m high ridge, narrow and dentate like the blade of a saw (fig. 15; cf. fig. 28).

When, on the other hand, a Pleistocene nunataq was enclosed by a couple of strongly eroding glaciers, it assumed a pointed bee-hive shape, like the Lofoten tinds. Characteristic examples of this type are Ũmánaq

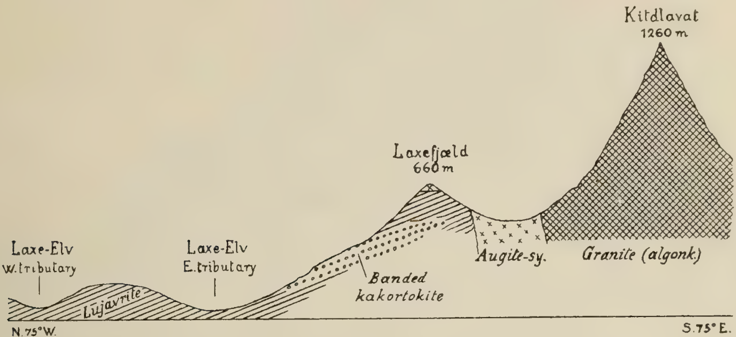

Fig. 15. Section of the nepheline-syenite complex at Kitdlavât. (Ussing).

(fig. 16, cf. fig. 22) and Ũmánatsiaq in Nordost Bay and, judging from pictures, also Cape Farewell (Ũmánarssuaq). Upon the whole the name of *ũmánaq*, i. e. the heart-shaped, or derivations from the same, will frequently be the appellation given to such isolated tinds.

Whereas planar ice-erosion prevailed in most regions, and linear, local erosion only in exceptional cases breaks the monotonous, rounded mountain forms, there are a few areas in West Greenland where the topography is throughout stamped by local glaciers. If the Polar ice pack permits the traveller to come within sight of the region round Cape Farewell, he is here given the opportunity of admiring a scenery, unparalleled in wild grandeur, and whoever passes through this region later in the season, by preference in early autumn when the new snow has wrapped its mantle round the mountains, receives an unforgettable impression of glacier-furrowed mountain giants, looking from dizzy heights across fiords and sounds, and of snow-white crests, where the ridges of the cirques stand out sharply, like knife-blades against the clear, light blue sky. Here the highest peak of West Greenland, the above-mentioned Sulugssugutâ, is situated; but its neighbours, Nalûmassortoq (2000 m) and Suikagssuaq (1850 m), are almost its equals in height.

Certain parts of Nordost Bay are by no means inferior to this, neither in height nor in fantastic beauty, and travellers familiar with the northern

Sukkertoppen District describe the latter as a similar scenery, the heights of which do not exceed 1500 or 1700 m, but where glacier follows upon glacier, and where mature comb-ridges and horns raise their peaks and pyramids between glorious cirques, thus creating a picture of unique wildness. (cf. fig. 29). As mentioned above, these land-forms are frequently described as Alpine, but there is a very considerable difference between

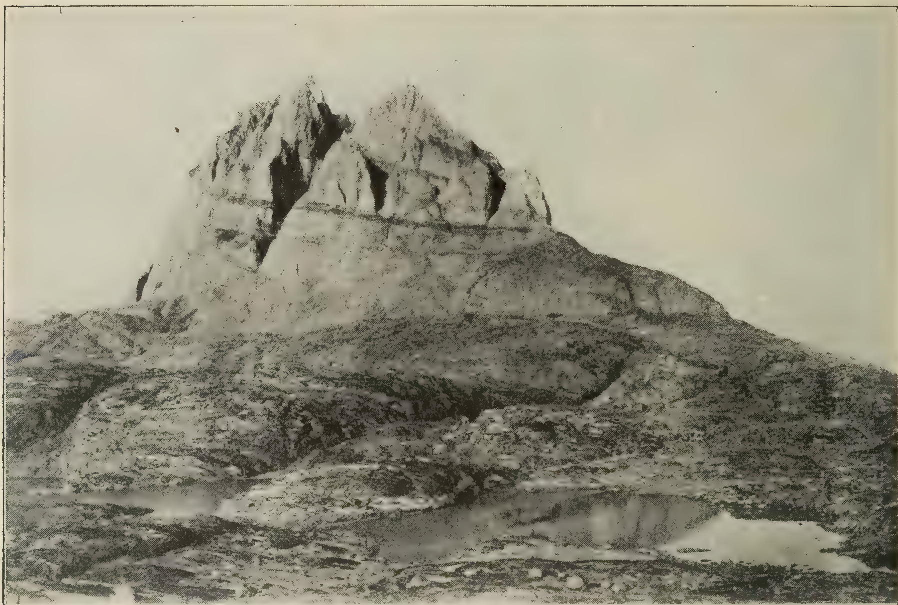

Fig. 16. The Ũmánaq tind in Nordost Bay. (Birket-Smith).
Notice dark bands of hornblende and ice-polished rocks in foreground.

them and those of the real Alps, as the glacial erosion of West Greenland extends right down to sea level.

The valleys of the primitive rocks are frequently so strongly influenced by recent weathering and humid erosion as to approach very nearly to normal erosional valleys, though also they at one time have been filled with ice. They occur both in the low, hilly regions and in the plateaux, and even many valleys in the more broken outer land show similar forms. On the Agpatsiait Peninsula, on Upernivik Island, on Sagdliaruseq and several other places in Nordost Bay the young, V-shaped valleys are divided by sharp, mature ridges, standing out boldly like marks of axes in the rock. Below, the spurs are cut off by the ice, the coast lines thus forming abrupt walls, but the valleys themselves, the texture of which is extremely fine, are entirely untouched by the ice. The great height and the splitting-up into islands and peninsulas seem to have favoured the recent erosion. In certain cases where the joints facilitated the destructive process, valleys have arisen, evidently also within post-glacial times. These valleys with

their young, almost vertical walls sometimes assume the character of true cañons.

The main valleys, particulary in the more elevated regions, bear distinct traces of the action of the ice; this holds good both in cases where the upper part still contains a glacier, and in cases where the glacier has already disappeared, and the valley ends in an empty cirque. These valleys have a typical U-shaped cross-section and drop down to the sea in irregular curves, deep where the eroding action of the ice has been strongest, and blocked by ice-polished ramparts where it has met with greater resistance (fig. 17). In some places the walls almost seem vertical until near the top, where they merge, with an abrupt bend, into a less steep slope, while in other cases the valleys are at a more advanced stage of glacial erosion, so that the U-shaped cross-section has almost developed into a semi-circle. Several of the valleys opening into the Ũmánaq Fiord are fine specimens of this type. The spurs in such valleys are cut off by the ice and now form a series of facettes along the sides of the mountains (cf. fig. 22) into which the side valleys open, hanging over the bottom of the main valley. At Godthaab Mercanton maintains having proved two glacial cycles, which in itself is quite probable, but requires further confirmation from other regions.

The bottom of the valley is frequently covered with till or, at lower levels, buried under coast terraces (fig. 18). In this manner the character of the valley is obliterated and, generally speaking, it would be most desirable if the Greenland valleys were made subject to a more detailed study, both as regards origin and stage of erosion.

The mutual distribution of mountains and valleys everywhere shows a close adaptation between land-forms and the structure of the rock. Though the Precambrian mountain chains have disappeared, the ancient strike is often distinctly visible in the arrangement of the mountains, as it is common

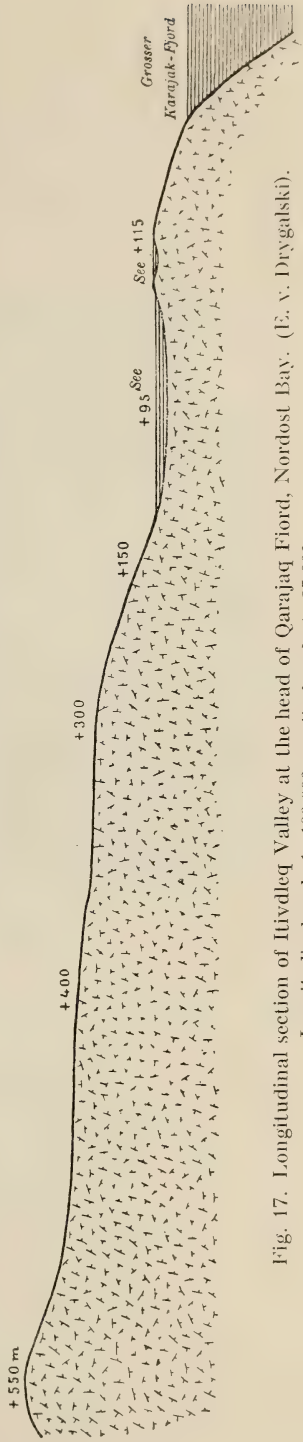

Fig. 17. Longitudinal section of Itivdleq Valley at the head of Qarajaq Fiord, Nordost Bay. (E. v. Drygalski).
Longitudinal scale 1 : 100,000; vertical scale 1 : 25,000.

for them to extend like ridges parallel with the strike. Where this is not the case, there is a deep-going agreement between the arrangement of mountains and the joints. There are few regions in the world which, to the same extent as the naked rocks of Greenland, lend themselves to a thorough study of the rôle played by joints in the modelling of a country, and it is now more than forty years since Kornerup succeeded in demonstrating how numerous valleys, large and small, are controlled by the joints and

Fig. 18. Valley in the coast mountains at Ungôrsivik, near the mouth of South Ström Fiord. (Th. N. Krabbe).

follow their directions. In subsequent pages we shall see that the same applies to the fiords of Central West Greenland.

This, however, brings us within closer range of the great and still unsolved problem, *viz.* the origin of land-forms in the Precambrian area. They are first and foremost due to erosion; so much is easily seen, and, likewise, that the most important, destructive factors to be considered are sea, rivers, and ice. The recent erosion is controlled without much difficulty, but the chance of error begins with the Pleistocene land sculpture, and increases disproportionally as soon as we attempt to work back to the share of pre-glacial times in the topography of the country.

When plateaux are met with in widely different parts of West Greenland, not only in well-defined landscapes, but scattered here and there, and merging gradually into the open, rounded scenery, the heights of which are all kept within narrows limits, then it is justifiable, here as in Scandinavia, to

look upon the plateaux as the original land-form into which, under special conditions, the more broken mountains were modelled. But what then is the origin of the plateaux? Whether their level to-day is high or low, it is a foregone conclusion that they only represent the roots of the original and now no longer existing mountains, and there are only three possibilities to be taken into account: they may be the remainder of an abrasion platform and so of marine origin, or they may be due to the Pleistocene inland ice, or else they may be due to humid erosion, in other words, either a glacial or a humid ("normal") peneplane. In order to form the present plateaux an abrasion platform as well as a peneplane would have to be raised considerably after levelling, but then, as pointed out by Otto Nordenskjöld, the Createaceous and Tertiary sediments show that an uplift of more than 1000 m has actually taken place at a geologically late period. As to this point there is, therefore, no difficulty—nor any hint as regards the origin.

It is, however, not very probable that the plateaux represent an abrasion platform. The hills standing out above the plains show no traces of marine action in the form of cliffs, but, on the contrary, in many cases they resemble typical monadnocks, and this result is also corroborated by other facts.

The importance of the inland ice in the modelling of the rounded land-forms has already been mentioned. Fridtjof Nansen is undoubtedly right when he states that glaciation, by a kind of selective erosion, will, as a rule, first and foremost contribute towards emphasizing the already existing relief, and, if this is true, even small inequalities in the pre-glacial surface may have given rise to essential differences at the end of an ice age. Whether, nevertheless, a glaciation of very long duration may end in forming an even surface, a glacial peneplane, is at best still open to doubt, and at any rate it is difficult to explain, how this glacial peneplane should have come to be formed in the Egedesminde District at a height of a little more than 100 m, but in Nordost Bay at a height of more than 1000 m above sea level. This would, however, have to be the case, for in post-glacial times no throw has taken place.

This difficulty is surmounted when we consider the plateaux as the remainders of a pre-glacial, humid peneplane, for the latter may very well have formed before the faults occurred in the basalt region. In this manner we may also better understand the close adaptation of the relief to the structure. According as the destruction advances, the drainage will be more and more finely adjusted to the structure of the rocks, and, as mentioned by Davis, a series of successive uplifts will contribute to an entire re-arrangement of the river systems, because the subsequent rivers, which are adapted to the structure, will gradually gain the upper hand. This is known from the Canadian as well as the Scandinavian peneplanes.

It would be interesting if geological facts were also in favour of the occurrence of peneplanes in West Greenland. Ussing demonstrated that the

Igaliko sandstone rests upon a peneplane which must, consequently, be Precambrian or early Cambrian (fig. 19). As the sandstone, however, is only preserved in consequence of a throw of at least 2000 m, there is no possibility of finding other relicts of it in this region on account of the average mountain heights. Ussing was also of opinion that the plateau visible in this locality, at a height of 700 or 900 m, was the remainder of another peneplane, and this theory is borne out by the fact that it seems to cut off sandstone as well as porphyry at the same level, irrespective of differences in hardness.

The Cretaceous sediments in the northern parts rest on a rather irregular gneiss surface, This clearly appears at Qaersuarssuk where, furthermore, under the sediments a distinct weathering crust covers the solid gneiss.

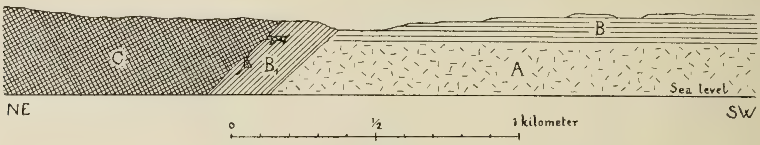

Fig. 19. Section of the Narssârssuk plateau near Igaliko. (Ussing).
A, granite peneplane. B, sandstone. B_1, sandstone and hornfels. C, augite-syenite.

Therefore, this old gneiss surface was, beyond a doubt, formed by erosion, but it cannot, as appears from the irregularities, have been a peneplane. The boundary between sediments and basalts seems to show that at the beginning of the volcanic action they were only slightly eroded.

However, it is not to be wondered at that the hypothesis of the peneplane is not supported by geological facts, as known at the present time; for in a country so poor in sediments as West Greenland, the occurrence of such a corroboration would rather be due to chance, and at any rate the language of Geography cannot very well be misunderstood. Consequently, the Precambrian area is supposed to have been worn down by erosion to a peneplane before or during the earliest Paleozoic age, and at least once after that time. In this peneplane a renewed humid and glacial erosion, after one or several uplifts, gave rise to the land-forms of to-day.

DRAINAGE.

Rivers. West Greenland is a country with innumerable water courses, but without any main river; for in the outer land, which is split up by fiords, the distances to the sea are everywhere so small that there is no room for brooks and rivulets to swell into larger water courses. The most important rivers spring from the melting water of the inland ice and are, as it were, intruders, while the others originate in some local glacier or in one of the thousand and one lakes scattered in such profusion over valleys and hollows. It appears from the preceding paragraph that the main valleys

are controlled by the weaker lines of the mountains, and so the greater rivers as a rule have a subsequent course, parallel with or in continuation of the great fiords. Many of the smaller rivers are, on the other hand, undoubtedly insequent.

Most of the rivers of West Greenland have a turbulent course, foaming along through narrow beds and in violent falls rushing from the hanging valleys into the main valley or out into the fiord. This juvenile stage does not agree very well with the character of the peneplane, which is supposed to be the older land-form of West Greenland, and it is, in fact, due to special causes, *viz.* partly to the uplift of the country, but principally to the process of rejuvenation which the whole area underwent during the ice age. Glacial erosion contributed essentially towards modelling the broken relief, reflected in the rivers. The only part of West Greenland where they have approached somewhat more closely to the grade and meander between clayey banks, is in the low hills of the interior of the central districts. Here it is possible to speak of mature courses. The same seems to apply to the fairly considerable river, Kûgssuaq, which runs through the longitudinal valley of Nûgssuaq Peninsula, and in size has been compared to the Rhône at the Lake of Geneva.

Special conditions obtain as regards those rivers which have formed the glaci-fluvial deposits at the heads of the clay fiords. In a few cases where the plains are sufficiently elevated, they have cut their beds into the latter, but where the plains are still in the process of formation, the rivers ramify across them in innumerable varying branches.

Lakes within the basalt zone are few and small, while the Precambrian areas constitute some of the regions in the world with the greatest abundance of lakes. From a mountain peak in these localities innumerable lakes of all sizes are seen glittering in the valleys, lakes, of which only an infinitesimal number have found their way into the maps. Where lakes have not been able to form, the moist hollows are at least filled with bogs with bleak, greenish-brown mosses or with sedges and nodding cotton-grass between black pools.

Like young river courses, so also lakes are anachronistic phenomena in a peneplane; but the same agents which rejuvenated the rivers also created new conditions for lakes. Directly or indirectly the greater part of them are the offspring of the former glaciation. It is true that a number of lakes depend upon the joints, as appears, for instance, on the small island, where the Ũmánaq settlement is situated; here there are two systems of fissures at right angles to each other and meeting in a small cruciform lake. Even in such cases the glaciation must, however, be supposed to have contributed towards the sculpturing of the lake basin, and many smaller lakes are undoubtedly entirely due to this action. Some quite small, circular ponds in the loose formations have, as mentioned above, been interpreted as glacifluvial pits (*Sölle*).

Most of the great lakes—and if known their number would no doubt prove impressive—occur in valleys and closely follow their outlines. Their formation is due to the fact that the through of the valley is somehow or other blocked by loose material, higher up in the valley as a rule by moraines, lower down by alluvium. Inside Kangerdluarssúnguaq in the Holsteinsborg District there is an opportunity of studying such a lake in the process of formation, as the accumulation is as yet so ineffective that the tides penetrate into the lake, the waters of which are consequently brackish. The greatest of the West Greenland lakes is, as far as is known, Lake Giesecke situated north of the mouth of North Strømfiord, only 10 m above sea level and 50 km in length; it is drained by a short, well-watered river traversing an alluvial terrace, a few kilometres in width. On Nûgssuaq Peninsula, 300 m above sea level, in the frequently mentioned longitudinal valley, are situated the so-called Steenstrup Lakes (Tasivigssuaq and Uigordleq), which together are 70 km in length, and farther east, at a considerably lower level, lies Lake Boye which, however, drains into Torssukátak Icefiord.

Several lakes are situated in the immediate vicinity of the inland ice, so that the latter discharges icebergs into them. Such a lake is, therefore, generally valled *iluliatik*, i. e. provided with icebergs. In one or two of these lakes peculiar conditions prevail.

In Frederikshaab Sermilik the first great "outpush" of icebergs is wont to take place at the end of June or the beginning of July. "The first outpush, according to the Greenlanders, is caused by the emptying out of the marginal lake Imaersartoq (i. e. the place which is pumped dry) on the south side of the glacier, when the water contained in it has reached such a height as to be able to lift the part of the glacier in front of it. The emptying out is then said to take place, accompanied by loud crashes as of thunder; water columns are flung into the air, and the icebergs formed in the lake are forced in under the ice of the glacier in front of it" (Grønl. II, p. 307). At the northern of the inner branches of South Isortoq there is another marginal lake, which is emptied every fifth or sixth year by the water-masses forcing the ice which separates the lake from the fiord.

In the steppe-like, hilly area there are many lakes without outlet, but water analyses are only at hand from one of them, Tarajornitsoq (i. e. the salt one) north of South Strømfjord. In July (1884) the salinity proved to be 3.4 per mille, or only a tenth of that of the sea, but of an essentially different composition. Calcium was entirely lacking; as compared with the amount of sodium there were relatively large quantities of magnesium and potassium, and carbonates played a great part in proportion to chlorides. Sulphates, on the other hand, only occurred in very small quantities[1].

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[1] The exact results of the analyses are the following: In 10,000 portions of water, there were 9.03 portions of Cl.; 0.76 of SO_3; 7.21 of CO_2; 5.10 of MgO; 11.11 of Na_2O and 0.79 of K_2O (M. o. G. VIII p. 59).

The Drainage Systems of West Greenland are, in most cases, not very interesting, because they generally centre in quite a regular manner round the larger fiords. It has formerly been shown that special conditions seem to prevail on Nûgssuaq Peninsula, where a fault, running parallel with the Vaigat, possibly controls the drainage of the Steenstrup Lakes.

Another region of particular interest in point of drainage is the Godthaab-Ameralik fiord system (fig. 20). The latter in reality consists of at least four different fiords with a common outlet, but divided by peninsulas and islands with crosswise sounds. In the regions north of this locality the western part of the country drains regularly to the outer coast, but in the whole of the interior, right to the latitude of Sukkertoppen, the water flows to the eastern branches of Godthaab Fiord, as most of the rivulets first gather in the great marginal lake Taserssuaq, which then, in its turn, through the short river Kûgssuaq, empties with a waterfall into the cove Ilulialik. The map shows that the divide between the said lake and the head of the fiord Niaqúngunaq is a short and evidently low stretch with numerous rivulets; further, the lake sends out an easterly branch in the exact continuation of Niaqúngunaq. This points towards Taserssuaq having originally drained into Niaqúngunaq, but that a capture has subsequently taken place, when Kûgssuaq by retrogressive erosion was connected with Taserssuaq.

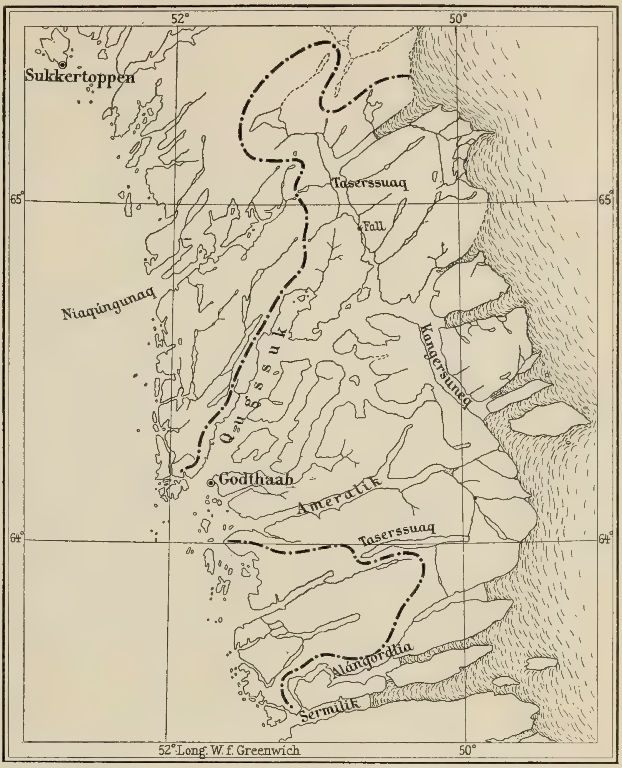

Fig. 20. Drainage area of the Godthaab-Ameralik fiord system.

On the south side of Ameralik similar conditions prevail, but at a less advanced stage. Here there are two great lakes, one of which, like the one mentioned above, is called Taserssuaq, while the other is a large unnamed lake on the margin of the inland ice. The former of these drains into Ameralik, the latter into Alángordlia Fiord; and, furthermore, these lakes are connected

by bifurcation. This absence of a distinct divide may be interpreted to the effect that the drainage system of the Godthaab complex is on the point of capturing the marginal lake from Alángordlia. As this system seems to have extended, or to be on the point of extending, both northwards and southwards, it is natural to look for the explanation of this in special conditions within the confines of the fiord complex, and in point of fact this system is quite unique in this part of the coast, where the rule is otherwise simple, uncomplicated fiords. Whatever the explanation to be given, an investigation on the spot is presumably essential.

THE COAST.

Coast Types and Littoral Movements. It has already been mentioned that the main trend of the coast of West Greenland seems to be determined by faults. In this manner the large, open Julianehaab Bay is also supposed to have originated. To geographers reviewing a detailed map of the coast with its myriads of islands and skerries, its labyrinth of widely branched fiords and jagged peninsulas, it will, however, be immediately apparent that other forces than those of the tectonic group have been at work. We are here confronted with a coast development so rich and a configuration so intricate as only paralleled in few other countries of the world. The greatest island, Disko, is 8300 square kilometres or only slightly smaller than Corsica (three times the size of Rhode Island), but to this must be added, along the whole distance from Cape Farewell to Melville Bay, an infinite number of smaller islands and skerries, their number, in the Egedesminde District alone, exceeding a thousand. Though no actual estimate has been made, it is evident that if the length of the coast, measured along a line connecting the extreme projections, were compared with the actual coast line, all incisions being included, the result would yield a quotient not much lower than the coast of Norway. The following table shows the length of the coast line in the trading districts of West Greenland[1]:

		Transport...	6692 km
Upernivik	2780 km	Egedesminde	2340 ,,
Ũmánaq	1840 ,,	Holsteinsborg	1510 ,,
Godhavn	540 ,,	Sukkertoppen	1920 ,,
Ritenbenk	480 ,,	Godthaab	2276 ,,
Jacobshavn	370 ,,	Frederikshaab	1520 ,,
Christianshaab	682 ,,	Julianehaab	3840 ,,
	6692 km	Total...	20098 km

[1] Measured on the 1 : 2,000,000 map, edited by the Commission for the Geological and Geographical Investigation of Greenland, by means of a pair of compasses, the points being 0.9 mm apart. It should be borne in mind that Alison Bay is not included in the coast line of the Upernivik District.

It is erosion, in particular glacial erosion, which has shaped the details of the coast line. As the Pleistocene glaciation revived the drainage, so it also rejuvenated the coast, and its action has been so strong, and the grooves drawn in the surface by the rough planes of the ice so deep that the coast, in spite of the later uplift, has, in the main, kept the character of a subsided coast.

However, the coast type to a certain extent is dependent upon the character of the rocks. In this respect the contrast between the Precambrian

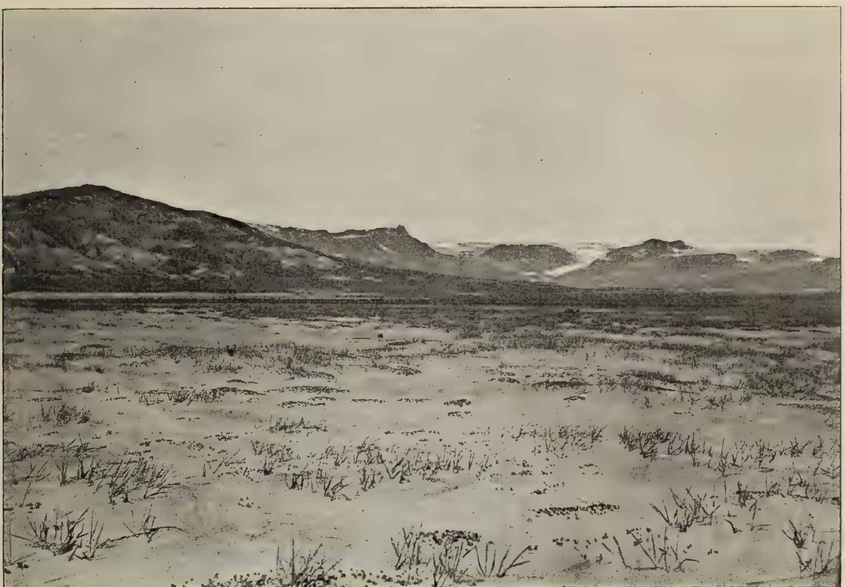

Fig. 21. Sand beach at Mudder Bay, Disko. (K. J. V. Steenstrup). Sandstone hills in background.

formation and the basalt is not particularly great. In the latter the development of the coast is, generally speaking, less pronounced and the incisions broader, although the occurrence of basalt breccia creates a finely jagged coastline with numerous small coves, skerries and isolated rocks.

The greatest difference in the coast type is, however, due to the contrast between the most resistant rocks, i. e. the Precambrian formation and the basalt on one hand, and the Cretaceous and Tertiary sediments on the other. The latter are so soft, and in consequence so greatly eroded and low that the uplift, which, apart from occasional alluvial terraces, has not left any considerable traces in the coast form of the other regions, in this case has given rise to a type which is otherwise looked for in vain in West Greenland. In several localities we here find a low sand beach (fig. 21). The sand is blown into dunes, where *Elymus*, *Mertensia* and *Halianthus* grow, and these dunes form spits of land which cut off brackish lagoons. In the latter

marsh is deposited, a kind of grass (*Glyceria*) helping to settle the particles of clay left by the sea at ebb tide. In other places the coast has passed this juvenile stage, and here the sea has formed cliffs. The alluvial plain in the Christianshaab District also falls off towards Sydost Bay with a 30 m high cliff.

Fiords and Sounds. The greater part of the ice-free outer land in West Greenland is, to an unusual degree, broken by fiords and sounds, and there is reason to suppose that many of these incisions are continued for some distance below the inland ice. There is no essential contrast between fiords and sounds, this difference being frequently caused by what might be called chance. A small subsidence would connect North Strømfjord with Ataneq Fiord as well as with Arfersiorfik, and the latter is only cut off from Sydost Bay by the alluvial plains formerly mentioned. The branches or even systems of fiords are therefore often separated by narrow necks only, which by the population are used as portages (sing. *itivdleq*) and sometimes save a detour of several days.

The lower the country, the more branched the fiords, everything else being equal. In the whole of the more elevated, southern part of the coast fringe Godthaab Fiord, the coast along the north side of Julianehaab Bay with Brede Fiord and Skov Fiord, as well as the Cape Farewell archipelago are the only places where the country is dissolved into actual complexes of islands, and in the two latter cases this seems to be due to a particularly intensive glacial erosion from the north-east as well from the north-west. Otherwise the fiords of the southern area are strikingly uniform in character. In straight or zigzag lines they cut across the country in a north-easterly direction, and in most cases either reach the margin of the inland ice itself or a constantly growing, glacifluvial plain in front of it. Whereas such a clay fiord is called *isortoq*, the appellation used by the Greenlanders for a fiord with a particularly productive glacier is *sermilik*, but in the southern area only Sermiligârssuk and Frederikshaab Sermilik are of real importance. In Disko Bay and farther north there are numerous icefiords of equal rank and at least five of first-rate dimensions, *viz.* Jacobshavn Icefiord, Torssukátak, Qarajaq Fiord, Karrat and Upernivik Icefiords.

The lengths of the fiords largely depend upon the width of the outer land and so, within the southern part of the area, increase northwards. Although there are some considerable fiords, as Tasermiut, in the neighbourhood of Cape Farewell, it is in the Sukkertoppen and the Holsteinsborg Districts that the longest incisions occur: South Isortoq, Evighedsfjord, South Strømfjord and North Isortoq. In the low country of this region the fiords, however, begin to be greatly ramified, and this is also the case with the longest fiord of West Greenland, North Strømfjord (187 km, of which the glacifluvial plain is 37 km) and the only slightly shorter Arfersiorfik. In Disko Bay the country is, finally, entirely submerged by

the sea. The soundings taken in this place are, however, too few to show whether the latter is anything but an ice-eroded transgression. As contrasted with their imposing lengths the gneiss fiords are narrow. The width as a rule varies from 2 to 3 km, being smallest at the mouth, where the tides consequently cause a tearing current, and it is a significant fact that one of the fiords in the Holsteinsborg District, which at its mouth has a width of 5.5 km, is called Ikertôq, i. e. the broad passage.

In the basalt region faults seem to have contributed towards the trend of the coast line, and presumably partly for this reason, partly also in consequence of the small resistance of the basalt as compared with the gneiss, the incisions are fairly broad and open. This applies to the Vaigat as well as to Nordost Bay, which divides into two large branches, Ũmánaq Fiord and Karrat Fiord. The short fiords in the Precambrian region at the heads of Disko and Nordost Bays are, however, interesting in so far as they receive some of the most productive glaciers of the world, *viz.* the Jacobshavn, Torssukátak, Qarajaq and Karrat Icefiords. North of the basalt region the height of the country once more decreases, at the same time that the inland ice shoots out far towards the west, and the coast consequently almost entirely splits up into a jumble of small and medium-sized islands.

On an average the fiords are deep, but unfortunately our knowledge on this point is very imperfect. A series of soundings carried out by M. C. Engell in the 33 km long Torssukátak Icefiord yielded the following longitudinal profile, reckoned from the margin of the glacier:

Distance in kilometres................	4.3	7.2	17.4	30.9	44.5	47.5
Depth in metres.....................	230	550	720	740	740	575

The transversal profile at a distance of 30.9 km and measured from the northern shore yields the following depths:

Distance in kilometres............	1.1	2.3	3.4	4.3	5.2	6.0	6.6	7.4
Depth in metres..................	520	640	735	735	740	735	725	725

These figures show, in the first place, that the depths are very great, and in the second that the shape of the bottom is that of an extremely regular basin. In other fiords the depth is still greater. On the Zoogeographical Expedition 1912 we used the dredge in Brede Fiord at depths ranging from 800 to 900 metres off the western part of Tugtutôq. From the Upernivik Icefiord the greatest depth in West Greenland, *viz.* 1055 m, is registered, and this is not much below the maximum depth of the Norwegian fiords. In the outer part of North Strømfjord the depths do not seem to be much less than 400 m, in the small fiords often not exceeding 200 m.

The longitudinal profile of the bottom frequently yields a more irregular curve than the one given from Torssukátak, but it is a fixed rule that the depth decreases greatly at the mouth, which is blocked by a submarine

Fig. 22. Agpat Sound in Nordost Bay. (A. Bertelsen).
The tind of Ũmánaq in back-ground. Cut-off spurs and talus at mountain foot to the left.

barrier. The latter rarely lies at greater depths than about 200 m, but, at any rate in Brede Fiord, the soundings taken midway of the mouth registered 700 m. This brings about a total change in the hydrography of the fiord, for while as a rule only the icy Arctic surface water gains access to the fiord whatever the depths inside the barrier, in this place also the warmer Atlantic water is able to make its way into it, a pronounced Atlantic fauna following in its train.

The basin form and the U-shaped cross section of the fiords (fig. 22) indicate the same origin as the ice-eroded, U-shaped valleys from which

Fig. 23. Ice-polished coast platform off Godthaab. (O. Bendixen).

they merely differ by being submerged. In many cases the fiord is continued in a supramarine valley with elongated lakes, indicating the stage which would be attained by all fiords of West Greenland if the uplift were sufficiently great. The arrangement of the fiords shows exactly the same features as those of the valleys, and an equal degree of adaptation to the structure of the rocks. Kornerup has proved that the main fiords, as well as their ramifications in the gneiss area south of Disko Bay, follow the joints, and that this is the cause of the fairly constant angles in which they meet. In the Julianehaab granite the trend of the fiords coincides with that of the most important dykes radiating from the batholites. This circumstance greatly strengthens the view that the surface of West Greenland is a former peneplane, subsequently elevated and broken up.

In the basalt area there are a couple of undoubtedly epigenetic fiords, the Uvkusigssat and Umîarfik Fiords, originally arising in the basalt, but now eroded down into the Precambrian substratum. However, as already mentioned, it is not improbable that tectonic movements have also here contributed towards the laying down of these fiords.

Coast Platform. In his comprehensive work on the bathymetrical features of the North Polar Seas, Fridtjof Nansen arrived at the conclusion that along the west coast of Greenland there is, as in Norway, a coast platform (*strandflat*), and this result was corroborated by the subsequent observations of Otto Nordenskjöld. The coast platform is a very low stretch along the sea, rising gently to 50 m or a little more, and then passing abruptly into the high country behind it (fig. 23). The width varies considerably,

Fig. 24. Taseralik Islands at the mouth of North Ström Fiord. (C. Wagner). Notice alluvial neck under formation in foreground and fully developed in background.

but may be as much as 10 or 20 km, at Godthaab even 29 km; a width of 50 km, such as occurs in a few places in Norway, is, however, unknown in West Greenland. The surface is never quite even, but distinctly eroded by the ice, which has given rise to a rolling plain and deposited till and erratic boulders, and sometimes also broken up the platform into innumerable islands and skerries, following the coast like a typical *Skærgaard* (fig. 24).

In the Julianehaab District the coast platform seems to include the small archipelagos off Frederiksdal, Nunarssuit and Kobbermine Bay, which all, from their position, are called Kitsigsut, i. e. the westerlies, and it is to be supposed that the same applies to the wealth of islets accompanying the coast between Frederikshaab and Frederikshaab Glacier. How conditions otherwise are in the Frederikshaab District and as far as Godthaab, as to that nothing is known. Off Godthaab the development of the coast platform is typical. Farthest out there are hundreds of quite small and low islands and submarine skerries, the Koek Islands or Kitsigsut with their

northerly continuation, and inside the latter is situated the quite low, south-western part of the great peninsula between the sea and the fiord branch Qugssuk. Between the mouth of South Strøm Fiord and Itivdleq the coast platform again occurs, both as a fringe of low land off high, in part Alpine mountains, and as a belt of islets and skerries, of which more particularly the group called by the significant name of Savssat (i. e. the crowding ones) is so low as to be almost submerged at flood tide. In the Egedesminde District the country is too low to permit of any typical coast platform, and as to the northern regions no information is at hand.

The explanation of this peculiar land-form has been looked for both in tectonic movements, in marine abrasion and in normal, sub-aërial erosion. However, none of these hypotheses were borne out by the observations of Fridtjof Nansen and Otto Nordenskjöld, and, no doubt correctly, both refer to the action of the ice. Fridtjof Nansen is here thinking of the ice-foot, but an ice-foot occurs in many places in the Arctic, where no coast platform has been recorded, and in West Greenland it seems as if a really typical platform chiefly occurs off comparatively elevated country. This gives added weight to the explanation of Nordenskjöld, when he looks for the origin of the platform in the so-called shelf-ice, a type of glacier which to-day does not occur in West Greenland, but is found in the Antarctic. Both writers draw attention to the fact that the fiords must be older than the coast platform, whereas, on the other hand, the till cover shows that the platform, generally speaking, is older than the latest glaciation. This seems to suggest chiefly interglacial age.

ICE AS A FEATURE OF SCENERY.

Glaciers. It is one of the most common, popular fallacies that Greenland is a country which, even in summer, is wrapped in a mantle of snow. Nothing can be more erroneous, and there are large areas of the west coast, including the Egedesminde, Christianshaab and Jacobshavn Districts, where the mountains are so low that not even local glaciers occur.

It is only when a certain altitude above sea level is attained that the snow does not melt completely in summer, but gradually forms *névés*, from which glaciers shoot down into the valleys. The line where the annual snowfall and melting are balanced is not any definite isohypsis, but depends upon the steepness of the mountain slope, its bearing towards the sun, and the prevailing direction of the wind. In order to be able to determine the climatic mean snow line many measurings must, therefore, be undertaken within the same mountain group, with a view to eliminating local influences, and such have not been carried out in West Greenland. Consequently, the snow line can only be given very approximately.

In the Julianehaab District, situated in the latitude of the Shetland

Islands and southern Norway, the "eternal snow" already occurs at a level of about 1100 m, whereas in Scandinavia it is necessary to ascend to the Arctic circle in order to find an equally low snow line. When traveling north in West Greenland we find, however, that the position of the snow line is not noticeably lower. On Disko merely the plateaux above 1000 m are covered with ice, and in Nordost Bay the line is only a little more than 100 m lower. This place is the West Greenland locality with the greatest abundance of glaciers, and here in one fiord, 45 km in length, Helland counted no less than 47 glaciers on both sides. In the Upernivik District many mountains are bare of snow, although their height exceeds 1000 m. The snow line in northernmost Greenland thus corresponds with the one found in Scandinavia in lat. 70° N., and it is an interesting geographical fact that the snow line from Cape Farewell to Melville Bay does not range within wider limits than in Scandinavia from the Arctic circle to North Cape. This is due to the fact that in Greenland the amount of precipitation decreases very materially towards the north.

On mountain peaks where conditions for the formation of a *névé* are at hand, valley glaciers or glaciers of an Alpine type will arise. Proportionally to the *névé* area they have a long ice stream shooting down into the valleys. They are common everywhere in West Greenland, where the mountains reach beyond the snow line. The plateau or Norwegian type is formed in elevated, but rather level places where the *névés* cover large areas, while the lobes issuing from it are comparatively small. The *névé* itself is thus a miniature inland ice, while its branches are Alpine. It is evident that this glacier type is especially to be looked for in the basalt region, where the land-forms particularly favour its development. Another transitional form to the inland ice is represented by the piedmont glaciers or the Alaska type. In the mountain heights Alpine *névés* accumulate, but the lobes coalesce into a continuous ice cap in the valleys. The thickness of the ice may even become so great that the lower peaks entirely disappear under its masses and only show as inequalities in the surface. This so-called Spitzbergen type is very closely related to the real inland ice. The conditions required for the development of the piedmont glaciers must be particularly favourable, and so are not to be found outside Polar or sub-Polar regions. In West Greenland the ice masses on both sides of Evigheds Fiord, as well as on the peninsula south of the Tasermiut-Lindenow Fiords, seem to belong to this category; but they are all very little known. It would be of importance to investigate the extent to which they are independent of the inland ice proper, with which they are connected by narrow ice bridges.

There is the great difference between the glaciers of Arctic and temperate regions that in the former they frequently reach the sea or at any rate come close to it. However, in southern West Greenland, naturally apart from the inland ice, only the huge piedmont glaciers extend down to the

level of the fiord, and even at the Vaigat none of the numerous glaciers reach so far. This is, however, the case in Nordost Bay with some glaciers on the north side of Nûgssuaq Peninsula, as well as on Upernivik Island. Ice cascades, on the other hand, occur in all areas where the country is sufficiently steep and elevated; the glacier here shoots beyond the mountain wall, loses its foothold and plunges into the deep. In some cases it reappears as a regenerate glacier at the foot of the mountain, but in others the ice masses fall directly into the sea. From Ilua Fiord as well as from Evigheds Fiord, descriptions are at hand of a spectacle, at the same time glorious and awe-inspiring, when enormous ice masses and huge stone blocks are flung down from dizzy heights. In these fiords there is a constant roaring and thundering, as of a distant canonade; boats must keep along the opposite side or in the middle of the fiord, and it is only with a feeling of uneasiness that the Greenlanders venture into these waters. The height of one of the ice cascades in Evigheds Fiord is given as 1600 to 1700 m, and by this immense fall the ice masses are crushed to powder, which rushes on through a steep, smoothly polished groove down into the fiord.

Only few measurings have been undertaken of glacier movements in West Greenland, and in general it can only be said that a local glacier on an average does not move more within a whole year than one of the great ice streams of the inland ice within twenty-four hours. In the case of a few of the glaciers of Nordost Bay information is at hand regarding their oscillations. The front of the Agssakâq Glacier was 250 m from the sea in 1850; only twenty-five years later the distance had increased to 500 m, and in 1879 to no less than 1150 m; but at that time there were signs of a new advance being imminent. In 1892-93 the distance had dwindled to 25 m, *viz.* within thirteen years it had on an average covered an annual distance of 86 m, but the movement was again strongly decreasing. The Sorqat Glacier in the same district showed equally great oscillations, though they did not move in time with those recorded above, and at the same time a third glacier in the neighbourhood, the Kûk Glacier, remained almost stationary. What the causes of these peculiar disagreements are, we do not know.

Winter Ice. There are many kinds of ice in the Greenland waters: winter ice, icebergs, west ice and *Storis*; the three latter, however, are not of local origin, but proceed either from the inland ice or from the seas off Greenland. As these forms of ice are discussed elsewhere, we will, in the present pages, only deal with the ice which during the winter is formed in and off West Greenland proper. During that season the cold is sufficiently strong everywhere to permit of ice forming along the coasts; when, nevertheless, many waters along the southern part of the country are open in winter, this is either due to the rapid current in many sounds or to violent gales, especially the foehns, which at that time of the year may rage with

terrible force. On the other hand, the forming of the ice is accelerated in closed bays, where there is a great supply of fresh water, but more particularly other ice contributes greatly towards the freezing-up of the waters. Icefiords with many icebergs freeze up at an early season, and grounded icebergs, as for instance off the coast of Disko—the "seam of the sea ice" as they are called by the Greenlanders—make the ice within firm and secure against gales. When, as happens in exceptional cases, there is *Storis* in the Julianehaab District during the winter, or when the west ice in the regions between the Vaigat and Sukkertoppen is set ashore, the freezing-up is at the same time earlier and covers a larger area. Therefore it is difficult to give definite rules for the winter ice, which may vary greatly from one year to another.

The sounds in the Cape Farewell Archipelago are, with a few exceptions, never frozen over, and then only if they are beforehand filled with *Storis*. In the long, sheltered Tasermiut Fiord slightly to the north of it, the ice, however, begins to form at the head as early as October, and it only disappears in April or May; in the outer part it is of shorter duration and may at any time be cut adrift by gales, whereas the mouth of the fiord is open at all times. Firm ice between the outer islands is not known in these regions.

The farther north, the firmer and more extensive the ice floe, while the influence of the latitude as regards duration is less pronounced. In the Godthaab Fiord system the inner branches are frozen over like the interior of the Tasermiut Fiord, but already the somewhat less protected parts are normally only frozen over from December to March; in the main fiord there is rarely anything but drift ice, and round the settlement ice is never seen in winter. Along the outer coast of this region ice can only form between islands and in particularly sheltered bays. In the Holsteinsborg District, i. e. at the Arctic circle, the floe lies firm within the outer islands from January to April, and even though it may be broken up by gales, it frequently drifts in between the islands and freezes up again. In this region the interior parts of the fiords are covered by ice all the winter from November, the outer ones from about Christmas, and on an average every fifth or sixth year the west ice penetrates into the fiords and freezes up with the winter ice. This district is the southernmost locality, where dog sledges are used.

At Disko Bay the icefiords freeze over as early as the end of September or the beginning of October, but in the bay and the Vaigat there is only ice from new year until April or May. Certain places in the Vaigat, and more particularly the sound between Disko and Arveprinsens Island, keep open until fairly late in the year, and therefore the broken ice is generally screwed up by gales, forming pressure ridges, which are a serious drawback to sledging. When the west ice sets against the coast of Disko, the bay freezes

over from the outside inwards, and under these circumstances great shoals of white whale and narwhal are often cut off and gather, in a state of exhaustion, in the holes which are still left open in the ice. These crowdings are known as *savssat*; and the Greenlanders on such occasions find an extremely profitable hunting.

In Nordost Bay *savssat* never seem to occur, as the freezing-up always begins from the inner part. Here the best floe of Greenland is to be found, firm and without hummocks, and here sledging culminates. The bay freezes over in November, being passable until well into June, and particularly in this district it happens that the ice in sudden, intensely cold and calm weather, forms as smooth as a mirror, so that the Greenlanders are able to carry on the so-called "smooth ice" hunting.

In the Upernivik District young ice is able to form, even in summer, on calm bays into which fresh water runs and where icebergs occur; but firm ice only begins to form in October and, off the outer coast where the dwelling places are found, at a somewhat later season. In the north part of the district it is possible to go everywhere by sledge from the beginning of November till the beginning of June, but, on the other hand, the innumerable islands which make up the main part of the district, cause extremely intricate tidal currents, and in consequence a quantity of rapids, the number and extent of which change from one month to another. These rapids, where the constant supply of new water creates favourable conditions for a rich development of the fauna, are essential to the population of these regions, and it is no wonder that the Upernivik Eskimo in point of daring and dexterity in moving on unsafe ice surpasses all other West Greenlanders.

Rapids where there is always open water, or where the ice at best is unsafe and cut up in the early spring, occur in all districts. Apart from Upernivik they are numerous in the Egedesminde and Godthaab Districts. In particular sounds and stretches outside salient points must frequently be avoided by sledging over land.

The lakes naturally freeze over at a somewhat earlier date than the fiords, and the ice also remains longer. Small water courses running across flat, stony places generally freeze to the bottom, so that the fresh supply of water spreads sideways and gradually forms a large ice-sheet; but greater and swifter rivers always continue their courses below the cover of ice. The brooks which originate in the "warm springs" of the basalt area are often able to continue their course under the snow, but at last, when the tunnel is closed by the frost, the waters are compelled to break up through the snow cover, forming there an oblong-conical ice shield which may attain a length of 20 m and a height of two or three metres. As the tunnel is prolonged backwards, the pressure of the water beneath the shield is increased, and the latter will consequently yield in the weakest spots and assume the

shape of a dome, or even burst when the pressure gets too strong. If the vegetation is incorporated in the ice shield, it will of course also be raised and then burst, and the fissures in the plant layer can be seen for several years after.

HISTORY OF TOPOGRAPHICAL DEVELOPMENT.

Pre-glacial Development. It is not our intention to represent the history of West Greenland through the changing periods, which task should be left to geologists, but before concluding the present chapter we will give a summary of the development of the scenery, more particularly directing our attention to the features which, to this day, can be observed by geographers in the topography of the country.

In West Greenland we recognize a very old country, where as early as the Precambrian era folding chains were formed; but even before the Cambrian period, or at any rate within the earliest part of it, these chains were eroded down to a peneplane. However, their strike and the joints of the rocks even now, millions of years later, make themselves strongly felt in the scenery.

In Cambrian times part of what is now South Greenland was transgressed by the sea, and the Igaliko sandstone was deposited, but as to the extent of the area over which this took place, we are unable to say anything for certain. Even before the process of sedimentation was at an end, glowing magma made its way up from the deep in the shape of huge batholites, and when sufficiently close to the surface they gave rise to a lively volcanic activity, through which process the porphyries and porphyrites above the sandstone were formed. The magma of the batholites had not yet consolidated, when parts of the area were depressed by a throw of at least 2000 m, preserving these peculiar formations within narrow limits, whereas what lay outside the sunken region in the course of ages disappeared through the agency of erosion. It is also possible to trace how, at least once, the whole of this area was eroded down to a peneplane, as has also been the case with the remainder of West Greenland within pre-glacial times; but when this took place, as to that nothing is known. Only solitary monadnocks rose above the peneplane.

In the Cretaceous period, presumably in the Gault, and subsequently continued in the Senonian and Eocene epochs, sandstone and shales were deposited in the north. These rocks, at any rate in part, are due to marine transgression, and it appears that at the beginning of the latter the surface of the Precambrian rocks was greatly weathered and rather broken. At that time the climate was subtropical or temperate and moist, and presumably the destruction was mainly of a humid character. Since then these sediments have been raised about 1000 m. It is supposed that even before there was time for the process of erosion to attack the sediments, the vol-

canic activity set in, and the latter then gave rise to great basalt layers; a faint after-effect of this activity may still be traced in the warm springs of this region. Perhaps about this time—whether before, during or after is not yet known—the faults came into force which, according to Lauge Koch, resulted in the whole of Greenland being, as it were, divided into two halves, the southern part of each being tilted up, whereas the northern part subsided.

In the basalt the sub-aërial erosion naturally began to make itself felt. According to Chamberlin there is some evidence that before any peneplane had been formed, this cycle was interrupted by another uplift, but the foundation of this hypothesis is still very weak. Also the peneplane shaped within the Precambrian area was uplifted during pre-glacial times; but we know nothing of the manner of combining these various upheavals, nor of the extent of the resulting destruction, when finally the ice age set in.

The Quaternary History denotes a turning point in the development, as we are from now onwards much surer of our ground. There is, however, one essential point which even now we are merely able to grasp dimly, *viz.* the origin of the insularity of Greenland, which by Wegener is referred to this comparatively late period. Otherwise the effects of the ice age make themselves generally felt in the topography of West Greenland.

This has already been described in full, and we need only recapitulate a few particulars: the removal of pre-glacial *débris*; the deposition of till, drumlins, eskers, and erratic boulders; the rounding of the ice-covered mountains and the shaping of *roches moutonnées* through the agency of the inland ice; the significance of local glaciers to the higher peaks, which stand out as nunataqs; the metamorphosing of pre-glacial valleys into U-valleys and fiords; the rejuvenation of the drainage, and the formation of the coast platform.

In post-glacial times the entire coast was at first considerably lower than to-day. Since then an uplift has taken place, least pronounced towards the south but increasing northwards, and by means of this uplift a number of raised shore lines and coast terraces were formed. Within the area of the soft and consequently most eroded sediments this uplift has been sufficient to create a coast type with dunes, lagoons and cliffs, which is otherwise not known in West Greenland, but apart from that, destructive forces have constantly been at work since the ice age, in the changing but always inclement climate, and sea, running water, ice, and wind constantly create new features in the physiognomy of West Greenland.

TOPOGRAPHICAL TYPES AND NATURAL PROVINCES

TOPOGRAPICAL TYPES AND THEIR DISTRIBUTION.

We are now able to lay down certain **Topographical Types** which, it is true, are characterized by the unsatisfactory investigations to which

the land-forms of West Greenland have been made subject. They may, however, do duty for a purely preliminary survey. The division made is in the first place due to the instructive work of Otto Nordenskjöld to which in the main has only been added the supplement, necessitated by the fact that his work merely deals with part of the west coast.

Farthest out we meet the coast platform created by a special combination of factors and appearing as a low, gently rising slope sculptured in solid rock and partly dissolved into islands and skerries. By an abrupt rise this platform passes into the higher country behind it.

Here the plateaux may be considered the most primitive relief, though within the former we must distinguish between three types. In the comparatively small and insignificant plateaux and plains within the Igaliko sandstone area, as well as in that of the far more extensive basalt plateaux, the character of the rock itself has contributed essentially to the land-forms, but how they are otherwise to be considered in detail is, in several respects, open to doubt. On the other hand, there is hardly any doubt that the plateaux of the Precambrian area are the remainders of one or more raised peneplanes. The topography is naturally influenced by Pleistocene glaciation, but as it seems in a comparatively small degree.

A surface form which in all probability is closely related to the plateaux is the low and rolling hilly country. It is true that it is somewhat more broken than the plateaux, with broad, flat valleys and low, gently outlined ridges; again, there is a certain difference between the southern and the northern part, dependent upon the fact that the latter is greatly cut up by fiords, whereas the former is more "continental" in character. The study of the pre-glacial land-forms is, however, rather difficult, because the glacial deposits, particularly in the "continental" parts, cover comparatively larger areas than elsewhere in West Greenland. Still, there is no doubt that this type represents a very old stage of erosion.

The most widely distributed land-form of West Greenland consists of dome-shaped mountains of medium height, which by gradual transitions merge into the gneiss plateaux as well as the low hills. They bear distinct traces of the glaciation, which left the forms strongly ice-eroded, with the exception of such peaks which always, or at certain times, have projected above the ice and which, therefore, were modelled by local glaciers and weathering. In this case we are certainly also dealing with the remainders of a raised peneplane, but it is likely that, even before the ice age, it had again been somewhat more eroded than the plateaux, although it is for the present impossible to ascertain the pre-glacial stage of erosion.

Whereas the said land-forms, to a higher or lesser degree, have been influenced by planar ice erosion originating in the Pleistocene inland ice, linear, local ice action has in some places given rise to a so-called Alpine topography. In the most characteristic regions the destruction has reached

a mature stage, and the cirques are divided by sharp comb-ridges and pointed horns. Alpine land-forms notably occur within the Precambrian area, but parts of the basalt region strongly approach a corresponding appearance.

Land-forms characterized by recent, humid erosion cannot be expected to occur to any large extent in West Greenland, because the rocks on an average are too resistant to permit of their development after the ice age. Only under special conditions a topography such as that occurring in certain localities of Nordost Bay seems to have come into existence, a topography where the margins of the island plateaux have been cut into sharp, mature ridges and juvenile, normal erosion valleys with a very fine texture. On the other hand, this type is the common one in the soft Cretaceous and Tertiary sediments, which at the base of the basalt mountains show a similar topography, only with a somewhat coarser texture.

The Distribution of the Land-forms is evidently largely dependent upon the rock (fig. 25). This appears immediately from the plateaux in the regions of the basalt and the Igaliko sandstone, and from the above-mentioned mature hills in the younger sandstone and shales. To some extent it is also supposed to apply to the types in the Precambrian rocks. The greatest area is here occupied by dome-shaped mountains which thus represent the ordinary stage of development. Alpine topography, on the other hand, seems to demand special conditions for the formation of cirques and, naturally, also a certain height above sea level. Presumably for this reason these land-forms are, in the main, limited to three regions of West Greenland, *viz.* the east side of Julianehaab Bay, the distance from South Isortoq to Kangerdluarssuk in the Holsteinsborg District, as well as certain parts of Nordost Bay. In the first of these areas the rock is granite, in the second gneiss-granite and in the third gneiss in almost horizontal bands or, in other words, everywhere rocks, the structure of which deviates from the ordinary, strongly folded gneiss. It is true that granite occurs on the north side of Julianehaab Bay, without any Alpine scenery, but this is evidently due to the fact that the country is rather low, in consequence of an uncommonly strong glacial erosion from two sides.

In the Precambrian area pronounced plateau forms are rare, being, as far as is known, limited to a small region within the Alpine country between South Ström Fiord and Kangerdluarssuk, as well as to the eastern part of Nûgssuaq Peninsula and one or two places in Nordost Bay. This distribution shows a peculiar agreement with the Alpine topography, and an investigation ought to be carried out with the object of establishing the occurrence or non-occurrence of plateaux in the Julianehaab District. It is tempting to assume that it may be the rock, which in the said localities has preserved the character of the peneplane in the shape of plateaux—as far as the horizontally banded gneiss is concerned it seems almost to be a certainty—

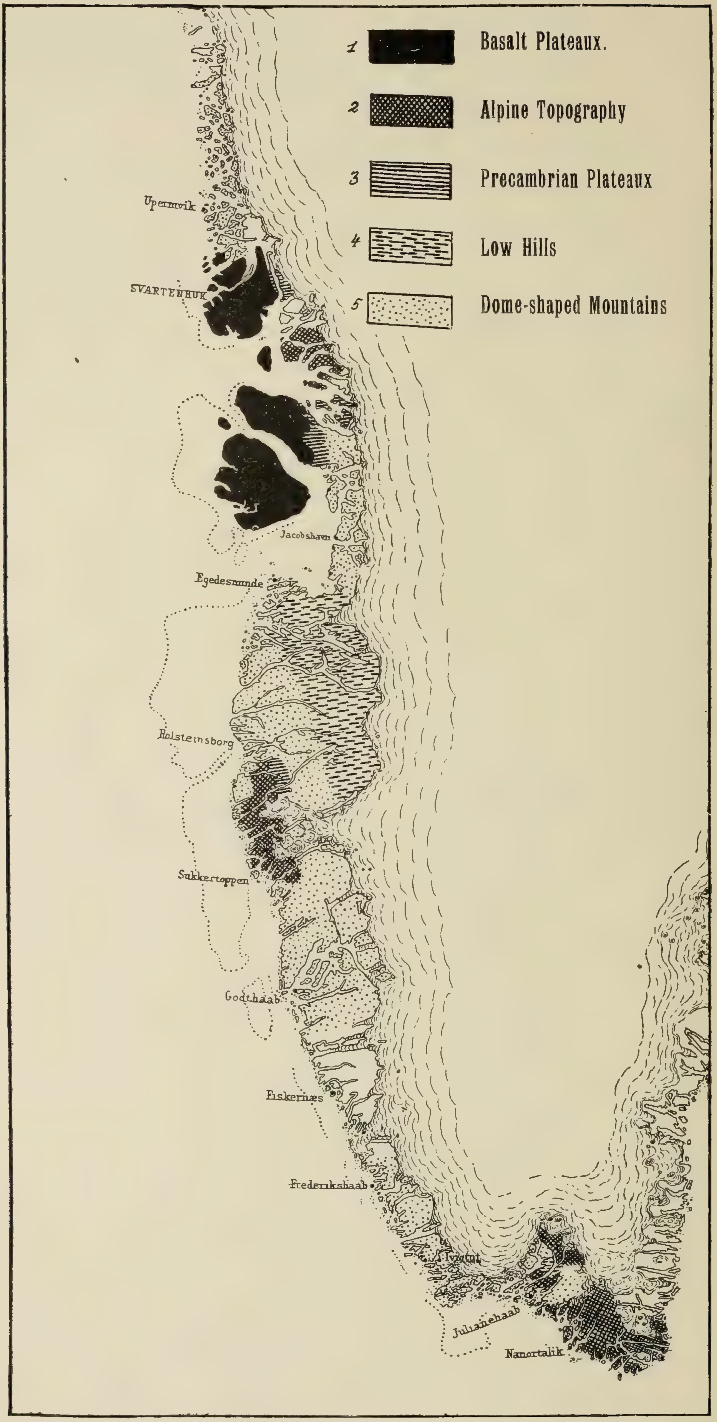

Fig. 25. Topographical types of West Greenland. (Partly after O. Nordenskjöld). Dotted lines indicate 200 metre isobases.

just as it is due to the character of the rock that the destruction of these plateaux resulted in the Alpine forms instead of dome-shaped mountains.

The low hilly country of West Greenland extends within the more elevated coast land, like a belt from the northerly Sukkertoppen through the Holsteinsborg District, increasing somewhat in width towards the north and finally filling up the greater parts of the Egedesminde District. The distribution of this topographical type is the hardest to explain. Whether it is continued southwards to any extent below the inland ice is not known. If the latter is the case, the rock surface of the whole of South Greenland might form a huge bowl, the margin being essentially higher than the centre, and this is possible, though on the other hand hardly probable, even when considering the enormous weight of the inland ice. The hilly country is a local type rather than a continuation of such an infra-glacial basin, but in that manner the explanation of its occurrence becomes still more difficult. As possible explanations Otto Nordenskjöld mentions tectonic movements, as well as a longitudinal valley running in the direction of Disko Bay, and also the occurrence of less resistant rocks, but at the same time he emphasizes that at present there is nothing in favour of any of these hypotheses.

In this connection there may be reason to mention that the explanation is perhaps to be viewed from a wider angle than West Greenland proper. At any rate it is striking that if Baffin Island, according to the theory of Wegener, is assumed to be in the immediate vicinity of Greenland, so that the "elbow" at River Clyde fills up Melville Bay, the huge Penny Highland is seen to correspond entirely with the elevated regions round Nordost Bay, whereas an enormous depression extends in the very continuation of the said low belt. This depression begins in Cumberland Gulf and is continued at the head of the latter in a narrow belt of Precambrian rocks, forming a low, hilly country, but it is presently submerged by the large and low-lying Nettiling Lake and, to the west of this lake, entirely buried under Cambro-Silurian limestone.

NATURAL PROVINCES.

Division of the Coast. After having dealt with the morphology of the individual land-forms and then viewing them collectively as certain topographical types, we finally proceed to the task of grouping these types into larger, natural provinces. Our starting point is the different character of the rocks, the trend and configuration of the coast as well as hypsometrical characteristics, and by this means we arrive at the laying down of four such provinces, *viz.* the Julianehaab Bay Region, the Southern Gneiss Area, the Basalt Region, and the Northern Gneiss Area.

These provinces correspond with one another, two by two. The two gneiss areas are the largest and form long, narrow strips, which both of

them slope northwards from considerable to very slight altitudes. Each of these is connected in the south with one of the other areas, which are smaller in extent. They mainly consist of igneous rocks, which in the southern province are chiefly Precambrian and plutonic, in the northern exclusively Tertiary and volcanic. In both places there are subordinate layers of sediments, which are entirely lacking in the gneiss areas, and both are mainly elevated.

The Julianehaab Bay Region is a unity from a geological, as well as from a botanical and an ethnographical point of view, and this repeats itself in its physiography. This region centres round the broad Julianehaab Bay, which forms an arc between the low Kitsigsut Islands and Nunarssuit. On the north side of the bay the ice-free coast fringe is very narrow, while on the eastern shore it widens considerably, the whole country forming, as it were, a wedge into the inland ice from the south-west. At the apex of the wedge there are still several nunataqs of considerable height (Aputaiuitsoq about 2200 m, Niviarsiat 1475 m), before the land is entirely buried under the ice.

The prevailing rock is granite, particularly the light grey Julianehaab granite, though other varieties and syenite occur in some places. Gneiss, on the other hand, only occupies a limited space. Most characteristic of this region is the area of the large batholites of nepheline-syenite, the Igaliko sandstone and the volcanic sheets. This area takes up the north-eastern part of the district and is bounded by faults. Most of the peninsula between North Sermilik and Tunugdliarfik consists of sandstone, and this also applies to the narrow isthmus between the heads of the latter and Igaliko Fiord, but through the sandstone the magma has made its way and given rise, partly to the sheets of porphyry and porphyrite resting, in some places, on top of the sandstone, and partly to the batholites. The smaller of these remarkable formations occupies both sides of the mouth of Tunugdliarfik Fiord, while the other and far greater one is at the head of the same fiord, centring round the southern branch. This geologically varying area is rich in very rare minerals; among the useful ones copper ore and graphite should be mentioned.

Both the tracts round Cape Farewell and the north coast of the bay are split up into large islands, probably on account of a particularly intensive, glacial erosion during the ice age. The Cape Farewell archipelago is separated from the main land by a narrow and somewhat winding channel consisting of Torssukátak, the outer part of Ilua Fiord, and the 60 km long and straight Prince Christian Sound or Ikerasagssuaq. Together they form a boat passage between the western and eastern coast. To the south of the passage several radiating sounds divide the country into numerous islands, the largest and easternmost of which is Christian IV Island, while Eggers Island is the southernmost one. The extreme south point of the latter is Cape Farewell,

a 300 m high, beehive-shaped hill. The south-western and south-eastern direction of the movements of the Pleistocene glaciers, which have gone to shape the radiating channels in the south, is still more pronounced on the north side of Julianehaab Bay with its innumerable islands, the most important of which are Tugtutôq between Brede Fiord and Skov Fiord, Qanertôq and Nunarssuit. Between the two island regions mentioned there is a stretch of typical fiord country on the east side of the bay, where the outer land is broadest. Beginning in the north there are, in continuation of Brede

Fig. 26. Alpine Scenery on Sermersôq near Julianehaab. (K. Stephensen).

Fiord and Skov Fiord—which in spite of their names are only sounds—North Sermilik and Tunugdliarfik respectively, and farther south are Igaliko Fiord, Agdluitsoq, South Sermilik and Tasermiut, the longest and most beautiful of them all (65 km). Among the islands only Sermersôq attains a considerable size.

In this region the coast platform seems limited to the masses of islets off Frederiksdal, Nunarssuit and Kobbermine Bay. The rounded mountains, otherwise so extremely common in West Greenland, are far from rare, but still of somewhat limited occurrence. In spite of the granite of which the country consists, they are, however, most characteristic of the north side of the bay, the reason being evidently the same forcible ice erosion which cut it into islands. On the east coast of the bay, which is less glaciated, there is another tract of dome-shaped mountains between Igaliko Fiord and Agdluitsoq, but generally it shows an Alpine topography, more splendid than most localities of West Greenland. Here the highest peaks of West Greenland occur, culminating in Sulugssugutâ (2240 m). There are, however, in the vicinity of the inland ice, right north of the previously mentioned

Fig. 27. The batholite of Igdlerfigssalik seen from Tuperssuatsiaq, south shore of Tunugdliarfik Fiord. (Ussing).
Distance about 35 kilometres.

nunataq of Aputaiuitsoq, numerous mountains of nearly similar altitudes, and in some places, as Sermersôq and the region round Igdlukasik, Alpine topography and considerable heights extend as far as the outer coast (fig. 26). Alpine forms also characterize the highest part of the batholites (Ilímaussaq 1410 m, Igdlerfigssalik 1725 m; fig. 27), which, however, are clearly distinguished from the granite mountains by their extremely small

Fig. 28. Redekammen seen from the West.
Mountain consisting of granite, plain in foreground of rapidly decaying augite-syenite.

resistance against weathering and, consequently, a comprehensive solifluction and strikingly poor vegetation. On the border of the Ilímaussaq batholite rises the jagged granite ridge of Redekammen or Kitdlavât (fig. 28). These parts thus stand out in dark, wild contrast with the adjoining, smiling and green-clad plateaux and plains of red sandstone, which were the centre of the old Norse settlement. With a certain justification travellers taking delight in imitative names have called this region the Italy of Greenland.

In this area the inland ice reaches its southern limit and, south of the isthmus between Tasermiut and Lindenow Fiords, merges into huge piedmont glaciers. In the Alpine regions the valley glaciers are naturally strongly developed, and glorious ice cascades are to be found in certain fiords. The ice conditions of the sea are first and foremost characterized by the Polar ice pack (*Storis*), because on its passage round Cape Farewell the ice is caught

and pressed together in the bay, which consequently at one time was an excellent sealing ground. Solid winter ice only occurs in the innermost branches of the fiords, whereas their outer parts, and in most cases also the sounds, are kept open by gales and currents.

The Southern Gneiss Area comprises the 1000 km long stretch from Julianehaab Bay to Disko Bay, and is, from a geological point of view, one of the most uniform places in the world. Only in the border region to the south does it show an approach to Julianehaab Bay, in so far as a couple of small patches at Arsuk Fiord are occupied, partly by a small batholite of nepheline-synite, partly by the so-called Arsuk formation, consisting of Precambrian, greatly metamorphosed sediments and igneous rocks. Here also the famous occurrence of cryolite is met with at Ivigtût. Of solid rocks there are chiefly gneiss and gneiss-granite, the latter coinciding in part with the Alpine region between Sukkertoppen and South Ström Fiord, and not even genuine granite occurs except as pegmatite dykes. On the other hand, till, alluvium and other loose formations play a certain, though modest rôle in the lowest lying parts.

In this area the outer land gradually increases in width from the south, until in the Holsteinsborg District it attains 180 km, but at the same time the heights seem to decrease fairly regularly, so that the country is finally submerged by the sea in Disko Bay, and only a narrow strip remains along the inner coast of the latter. The whole area is greatly broken by narrow fiords, increasing in length and ramification from south to north, according as the outer land gets broader and lower. South of the great Frederikshaab Glacier, where the inland ice advances as far as Davis Strait, the fiords are still rather short, the most important being Sermiligârssuk, Frederikshaab Sermilik and Kvane Fiord or Kuánersôq, ranging between 38 and 46 km. The two first mentioned are the only real icefiords south of Disko Bay, though their glaciers are very inferior to the enormous ice-streams of the north. There are, of course, numerous islands along this part of the coast, but none of considerable size. Farther north we pass several other fiords—Björne Sound or Agdlumersat, Græde Fiord or Kangerdluarssugssuaq, and Bukse Fiord or Kangerdluarssúnguaq—until, near Godthaab, we meet a fiord-complex which both in regard to size and configuration is quite unique in this part of the coast. It may be described as two fiords, Ameralik and Godthaab Fiord, having a common outlet; but whereas Ameralik is a 74 km long and narrow incision of the ordinary type, Godthaab Fiord widens shortly inside the mouth to a broad basin, which is divided into three channels by means of islands, *viz.* Storö and, north-west of it, the smaller Björneö and Sadelö. Farther inland the basin contracts once more and sends off radiating branches, the longest of which is called Kangersuneq. This peculiar configuration, as well as the drainage system of the surrounding country, make the Godthaab Fiord complex a promising field for future studies. Be-

tween Godthaab and Disko Bay the country is traversed by some of the finest specimens of fiords in the world, for instance. South Isortoq (44 km, but continuing in a glacifluvial plain of the same length), Evigheds Fiord (88 km), South Ström Fiord (175 km) and North Isortoq (more than 100 km, but the head is not mapped). As a rule these fiords are narrow, with an essentially north-easterly trend, which is closely dependent on the joints of the rock. According as the country becomes lower, the ramification increases. The northern shore of North Ström Fiord, which is the longest of

Fig. 29. Local glaciers and fretted comb-ridges on Hamborger Land near Sukkertoppen. (Bjørn Jessen).

all West Greenland fiords (187 km, of which the glacifluvial plain takes up 37) is severed by long and narrow channels forming great, island-like peninsulas. Arfersiorfik is not much inferior in length and still more complicated. It is easily understood that the greatest islands, as Sarqardlît, Ikamiut, etc. are found in this low lying and fiord-cut country south of Disko Bay. In the narrow coast fringe on the east side of the latter the fiords are of course very short, but two of them, Jacobshavn Icefiord and Torssukátak, receive glaciers which are supposed yearly to produce 18 to 22 milliard tons and 3 to 4 milliard tons of ice respectively. Inside Disko lies the great Arveprinsens Island.

The coast platform is developed in its typical form in the southern part of this area, both as a *Skærgaard* and as part of the mainland, the latter particularly at the mouth of Godthaab Fiord. In most places of the country dome-shaped mountains occur, frequently forming rounded ridges in the original direction of strike or joints. The highest are found in the south, e. g. Kûngnait (1395 m), Norssaerserfik (1645 m), Qingaq (1630 m), etc. Some

Fig. 30. View of the low country near the mouth of Arfersiorfik Fiord. (Birket-Smith).
In foreground camp-site of Qiterdleq, at end of portage from Iginiarfik.

peaks are supposed to be monadnocks, and several of them are greatly eroded by extinct or still existing local glaciers. Alpine scenery to any large extent, however, only occurs in the gneiss-granite area between South Isortoq and the Holsteinsborg Kangerdluarssuk (fig. 29). It comes very close to the outer coast, but does not reach far inland, and the altitudes do not exceed the average, probably culminating in the barren alps north of South Ström Fiord (about 1600 m). To the east of this zone there is a small area, where plateaux prevail. Inside the plateaux, after a zone of rounded mountains has been passed, follows the characteristic, low and hilly country extending farther towards Disko Bay (fig. 30). It occupies the north-eastern Sukkertoppen District, the interior parts of the Holsteinsborg District and most of the Egedesminde District and, on account of their peculiar climatic conditions, the eastern parts make the impression of a "Polar steppe." The narrow coast fringe inside Disko Bay is again somewhat higher, particularly Arveprinsens Island, which in some places attains 700 to 800 m.

Alongside the local valley glaciers which occur wherever the height is sufficiently great, *viz.* in the north as far as and including the Holsteinsborg District, huge piedmont glaciers occur on both sides of Evigheds Fiord, in which no less than 40 ice-streams have been counted, and it is hardly due to chance that their occurrence coincides with the gneiss-granite and the Alpine topography. They are connected with the inland ice, but are supposed to be rather independent of it. In several localities within this region there are impressive ice cascades. The winter ice along the southern part of the coast is not much better than in Julianehaab Bay, and only the inner parts of the fiords are sure to freeze over. It is not till the northern Sukkertoppen District that fairly solid ice begins to form between the outer islands, though under present conditions it does not pay to make use of dog-sledges south of the Holsteinsborg District. The west ice, which frequently approaches the coast during the winter, may, however, contribute towards making the ice cover more solid.

The Basalt Region comprises Disko Island, the western half of Nûgssuaq Peninsula to a somewhat winding line running from Kûgssuaq in the south to Kûk in the north, and most of the Svartenhuk and Ingnerit Peninsulas. There are also some smaller islands, notably Hare Island off the Vaigat, Ubekendt Island in Nordost Bay and Skalö off Umîarfik Fiord, and Cretaceous sediments occupy the south-western corner of Upernivik Island. It is highly probable that the eastern boundary of the whole region is due to faults. Precambrian rocks are only to be observed in a few, small localities on Disko, and where Uvkusigssat and Umîarfik Fiords have cut through the overlying rock, but otherwise the whole area consists of basalt varying with thin layers of tuff and frequently resting upon Cretaceous and Tertiary sandstone and shale. The sedimentary rocks contain some coal beds which are worked at Qaersuarssuk. The sediments form narrow strips along the

south-eastern and north-eastern coast of Disko and the south and north sides of Nûgssuaq Peninsula, lending to the coast the character of an elevated shore with brackish lagoons, etc. Though genuine fiords occur in the basalt of western Disko (Disko Fiord, Mellem Fiord and Nord Fiord), dislocations seem to have acted strongly upon the formation of the Vaigat, Nordost Bay with Uvkusigssat Fiord, and Umîarfik Fiord.

To a larger extent than elsewhere in Greenland the recent humid erosion has left its traces on the sediments, which present the appearance of a rather low, hilly country of mature stage. On the other hand, the volcanic

Fig. 31. The Apostel Mountain near Godhavn, Disko. (Rikli).
Basalt layers clearly visible. Ice-polished gneiss in foreground.

formations give rise to high mountains of a prevailing plateau character (fig. 31), which, however, in certain localities may approach Alpine forms. The greatest heights are attained on Nûgssuaq Peninsula where several peaks reach about 2000 m, as Qilertínguaq and others. Disko and especially Svartenhuk Peninsula are generally somewhat lower. One of the highest mountains of Disko is Ivnârssukasik on the southern shore of the Vaigat (1725 m), but in the interior the average altitudes of the peaks do not exceed 1200 to 1600 m.

The glaciers are essentially of the plateau type, and in certain localities form ice cascades. Nearly all plateaux of more than 1000 m are covered with enormous *névés* which give rise to innumerable glaciers. The winter ice is of long duration and solid enough to be of still more vital importance to the population than farther south, though even in certain parts of Disko Bay it may break up with gales. In this place the west ice sometimes causes such an abnormal state of affairs that the bay is frozen up from without. Nordost Bay is considered as having the best and smoothest floe in West Greenland.

The Northern Gneiss Area is somewhat shorter than the southern one, but especially far narrower. It begins with the head of Nûgssuaq Peninsula, extending inside the basalt region, until the latter ceases close to Prøven; then it continues northwards and, in its turn, gradually disappears under the glaciers of Melville Bay. The distance between Tugtulipaluk and Tugtuligssuaq, which is a continuous wall of ice with very few nunataqs and practically no islands, makes a better, geographical division line be-

Fig. 32. The gneiss plateau of Storö seen from the Ũmánaq Settlement. (Birket-Smith). Distance across the sound about 8 kilometres.

tween West Greenland and the Thule District than the administative boundary across Holm Island. Gneiss and chrystalline schists are the most common rocks, whereas granite and other igneous rocks only appear in very small quantities. No mineral resources of importance have been located.

Owing to the narrowness of the area the fiords are very short, but on the other hand the southern ones receive some of the most productive glaciers of the world. Ubekendt Island which wholly, and Upernivik Island which partly belongs to the basalt region divide the great basin of Nordost Bay into two main branches, Ũmánaq Fiord and Karrat Fiord, and each of the latter again goes to form several minor incisions which cut through the Precambrian coast land right to the inland ice. All of them receive considerable glaciers, and both Qarajaq Fiord and Karrat Fiord, in its more restricted sense, rank among the five first-rate icefiords of West Greenland. The production of the former is calculated at 15 milliard tons a year;

the latter has not been measured, but is supposed to be in no way inferior. North of the Ingnerit Peninsula the only real fiord is, strictly, Lakse Fiord between Prøven and Upernivik. The coast is split up into an infinitude of islands, most of them rather small, but often forming parallel lines with fiord-like channels or open bays between them. In this way we have from south to north: Upernivik Icefiord, Tasiussaq Bay, Giesecke Icefiord, Sugar Loaf Bay, Inugsulik or Ryder Bay, and Alison Bay. The former of these incisions is referred to as one of the five main icefiords of the country; very little, however, is known about the ice production of the northern fiords, all of which receive several glaciers, but that of Giesecke Icefiord, at least, is very considerable.

Also this area attains the greatest heights in the south, where the mountains of Nordost Bay are not much inferior to those of Julianehaab Bay, but it gradually becomes lower in a northern direction. On Nûgssuaq Peninsula, as well as on Storø or Sagdliaruseq (fig. 32) and other islands of Nordost Bay, the country rises in the shape of huge plateaux to altitudes of 1400 to 1500 m. In other localities of the bay Alpine scenery is developed, which is greatly impressive in its jagged splendour. Here the greatest heights of the area occur; many of them attain 2000 m, and near Karrat Icefiord the wild peaks of the Akuliaruseq Peninsula rise 2150 m above sea level. Nearest the inland ice more rounded forms prevail, and the latter are also, in certain places with some approach to the plateaux character, typical of the Upernivik District. In Alison Bay, before the country is entirely overcome by the ice, it rises to 840 m in the peculiar, vertical peak of Devil's Thumb. Nordost Bay is one of the regions in the world with the greatest abundance of glaciers, and it is quite impossible to give their exact number, but in the Upernivik District their multitude decreases owing to the small amount of precipitation. The winter ice in Nordost Bay was mentioned in connection with the basalt area; farther north a multitude of rapids make the ice cover less secure.

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THE PHYSIOGRAPHY OF NORTH GREENLAND

BY

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The most recent investigations in North Greenland have shown that this northern fourth part of the country is one of the most interesting regions, geographically and geologically, of the Greenland continent. The present author commenced an investigation of North Greenland in 1916, which, with various interruptions, he continued until 1923, and thus the following description is in all essentials based on his own investigations.

Previous to 1916 we knew the north coast of Greenland in its main features. Also the edge of the ice cap had in some places been correctly mapped, and thus the geographical distribution of land, ice cap, and sea was known in its broad features, although a closer investigation has modified the details to some extent. As a main result of the new geographical investigation and survey may be mentioned the discovery of the wide, as yet unknown areas along the north coast of Greenland from Kane Basin to Peary Land. Including Inglefield Land and Peary Land, we find a series of ice-free areas, which in size are equal to, or even surpass, the ice-free area in West Greenland from Disko Bay to Godthaab Fiord.

This description comprises the coast from Holm Island which forms the northern boundary of the Upernivik district, to Northeast Foreland, the easternmost point of Greenland. About one fourth of the Greenland coast extends between these two points. The boundary is partly administrative, and partly conventional, but not geographical, so we have to divide North Greenland into a series of morphological elements, some of which are only parts of a larger unit, also occurring outside the area described in this section.

OROGENETIC SUMMARY.

Previous to my journey north of Greenland I was enabled to define the structural elements in Greenland. (Lauge Koch: Some new features in the Physiography and Geology of Greenland. Journal of Geology, Vol. XXVI, Nr. 1, 1923). In this work are mentioned three elements occurring in North

Greenland, viz. 1) the northern gneiss plain, 2) the great sediment plateau, and 3) the Caledonian Folding.

During my last expedition these elements were further investigated and

Fig. 1. Cape Morris Jesup, Peary Land. (Lauge Koch).

their exact limits defined; and another element, hitherto unknown in Greenland, was discovered, viz. a (Mesozoic?) fault zone, comprising the Cape York district.

1) The northern gneiss plain. In the paper mentioned above, it has been pointed out that the surface of the ice cap in North Greenland is an extra-

ordinarily low-lying area. This is due to the fact that the gneiss plain from the great heights farther south slopes gradually towards the north. This is distinctly seen when travelling along the west coast of Greenland.

The western boundary of the gneiss area is formed by the coast itself

Fig. 2. The structural elements of North Greenland. (Lauge Koch).

up to Cape York, in the Cape York district, however, by a large fault, the average height of which may be estimated at 800 meters.

The northern boundary of the gneiss plain is of a purely topographic nature, since there is no geological boundary to the north. The gneiss plain can be traced northward to sea-level, but the sediments which cover it here show by their composition that the gneiss plain must undoubtedly be continued with a slight descent towards the north. The entire eastern portion of the shallow Kane Basin is floored by gneiss. Hence we must be content to state where the gneiss goes beneath sea-level, and thus the north coast of Inglefield Land, which strikes east-west, forms the northern boundary of the gneiss plain.

In East Greenland, the bottom of Danmark Fiord is known to be floored by gneiss, but its northern limit of exposure has not yet been determined.

2) The great plateau of sediments is bounded on the south by the gneiss plain, on the west by the Cape York fault zone, on the north by the Caledonian Folding, and on the east by the Atlantic.

These limits are purely geographical, the original geological boundaries were no doubt of far greater extent. How far to the south the sediments formerly extended over the gneiss plain it is now impossible to ascertain. The fault zone in the western part of the Cape York district is a much later limitation of the plain, while to the north there is the Caledonian Folding, which consists chiefly of the metamorphosed strata of the plateau of sediments.

It is very difficult to state the maximum thickness of the strata of the plateau of sediments. The strata of Algonkian age vary from 200 to 1000 meters, the Cambrian strata have a maximum thickness of 500 meters, the Ordovician strata appear pretty constantly to be 800 meters, and the Gotlandian strata, whose numerous unconformities show that considerable series of strata have been eroded, average about 600 meters.

It is very uncertain, whether these series of strata overlie each other in their maximum thickness, but it is at any rate quite certain that very thick strata of sediments have been deposited previous to the forming of the Caledonian Folding.

Throughout the vast area of the plateau of sediments not the slightest indication of later flexures, faults, or foldings has been observed.

3) The Caledonian Folding extends over the remaining northern portion of Greenland and forms the north coast of the country. The western part of this mountain range was investigated during the Second Thule Expedition, and on this journey we succeeded in determining its limits in Northwest Greenland. On the other hand, it was a disappointment when it proved impossible to survey the greater part of them eastward into Peary Land, because here the mountains are of an Alpine character, partly inaccessible, partly covered by glaciers and rock débris. However, the central part of the mountain range in Peary Land seems to be composed of gneiss and granite (mica-schist is found stationary west of the northernmost point of Greenland), and, on the whole, this, the eastern portion of the mountain range, appears to be far more folded and metamorphosed than the western part.

In contrast to the greatly metomorphosed strata of Peary Land, it is still possible in the western part of the mountain range to distinguish the fossiliferous Pentamerus limestone and the graptolite shales.

4) The fault zone of the Cape York district is bounded by a large fault, extending from Etah to the interior of Inglefield Gulf and farther southward to Dead Men's Fiord.

THE COMPOSITION OF THE GREAT PLATEAU OF SEDIMENTS.

The sediments rest either on gneiss or on batholithes of syenite and diorite, and it is evident that the Algonkian sea transgressed over a plain which erosion had made extraordinarily level.

Algonkian strata occur in three different areas:

a) The fault zone of Cape York. The greater part of this district is made up of Algonkian sediments. The basal conglomerate is very thin everywhere, and the Cryptozoon reefs are but sparsely developed, whereas white sandstone is of common occurrence and in many places passes into a highly micaceous greywacke. Dolomite occurs locally, sometimes in thick strata, but in many places it is replaced by a peculiar black shale, which bears a superficial resemblance to the graptolite shales.

b) Inglefield Land. Here the sediments have been eroded to a very great extent and what remains of the Algonkian strata is only about 200 meters in thickness. In the western part, Cryptozoon reefs are particularly well developed, but otherwise white sandstone with a diagonal structure prevails. Dolomite strata are highly developed, but black shale is not seen at all.

c) Mylius Erichsen Land and the surrounding regions. South and west of Independence Fiord occurs a great plateau of Algonkian sediments, sloping gradually northeast to sea-level from an altitude of 1200 meters. Profiles of up to 1000 meters in height and predominantly of red sandstones occur here. However, it must be noted that the sandstones of this area have everywhere been penetrated by eruptives, and hence their original thickness must no doubt have been considerably smaller. Basal conglomerates and purple sandstone also occur, however, in the form of boulders, whereas neither dolomites nor shales were met with here. These strata greatly resemble the white sandstone of Inglefield Land, and commonly have a diagonal structure.

All the Algonkian sediments appear to have been deposited in a dry climate. This is seen from their red colour and from the unweathered felspar grains, which occur principally in the lower strata. The entire series of strata has, at any rate, been deposited in shallow water, and some of them may even be desert formations. Ripple-marks and sun-cracks are found throughout the whole series, including the dolomites.

Throughout East and West Greenland there is evidence of eruptive action after the deposition of the Algonkian strata. In the Cape York district and in Inglefield Land, the eruptives are mainly restricted to the western and southern regions, whereas they are seen but seldom in the interior of Inglefield Gulf. These eruptives are principally basic, and almost exclusively diabases, appearing as dykes or as extended sills.

In Northeast Greenland there are also considerable quantities of diabases, but in the main the eruptives here are acid. Along the south coast of Indepen-

dence Fiord there is a fine profile nearly 50 kilometers in length, which exposes no fewer than four great laccolites, and throughout the whole area there are evidences of eruptive action.

Fig. 3. From the interior of Brönlund Fiord. (Lauge Koch).

Cambrian strata were discovered in North Greenland in 1922. After the Algonkian eruptions had ceased, the surface was again peneplained by erosion, and the lower Cambrian sea transgressed over a rather level plain. On the northern coast of Inglefield Land, the deposits of this sea commence

with conglomerates which alternate with sandstone, the combined thickness reaching about 30 meters. The conglomerates contain, among other things, blocks of diabase, averaging the size of a hand; but finergrained strata also occur, which suggest fragmental limestone, and contain specimens of wellpreserved brachiopods and trilobites. This is the so-called Wulff River Formation, whose fauna represent the second highest zone of Lower Cambrian. The conglomerates are overlain by highly fossiliferous oolitic limestone. This formation has been named Cape Kent Formation after the place where it was found, and its fauna represents the top zone of Lower Cambrian. Above these strata occur Middle Cambrian strata, the so-called Cape Wood Formation, which is made up of conglomerates overlain by compact limestone. The following strata contain only few fossils, but may probably be referred to Lower Ozarkian (Cape Frederik VII Formation).

Then follow intraformational conglomerates (Cass Fiord Formation) overlain by greyish yellow limestone (Cape Calhoun Formation), which both belong to Upper Ozarkian. Above these strata comes very fossiliferous limestone (Nunâtame Formation) belonging to Upper Cambrian, overlain by the so-called Gonioceras Bay Formation, consisting of dark compact limestone (Black River), and above this the very fossiliferous Cape Calhoun Formation, belonging partly to Trenton and partly to Richmond.

In fact, strata of Ordovician age extend in a wide belt from Kennedy Channel to Independence Fiord. Along the coast these formations tend to form great vertical cliffs, in some places even overhanging.

As will be seen from the above, the Cambrian and Ordovician series of strata is not continous, since the oldest zone of Lower Cambrian and also Upper Cambrian are lacking. The same is the case with Lower Canadian and Chazy. All these gaps in the series of strata are generally represented by almost invisible unconformities, and only a closer examination of the fossils will show the gaps.

In the Silurian strata, extending as a belt from Kennedy Channel across Independence Fiord north of the Ordovician strata, this is not the case. Apart from the Cambrian basal conglomerate, containing Archeozoic and Algonkian material, all the Cambrian and Ordovician conglomerates are intraformational, since they contain blocks of limestone from the underlying strata.

Towards the end of Richmond the land rose again, so that the younger Ordovician strata have no doubt been deposited in very shallow water, and consist of brachiopod limestone. The rise of the land continued, and considerable portions of North Greenland rose above sea-level. A long time of severe erosion followed, which in several places penetrated the Cambrian and Ordovician strata, and even penetrated to the Algonkian and Archeozoic strata, since blocks from these formations have been deposited in a Silurian conglomerate. Later the land again subsided, and black shales containing

brachiopods and trilobites were deposited, which may be linked with Lower Silurian. These strata also contain Monograptus lobiferus, indicating correlation with the Lower Birkhill in England. The shales are overlain by limestone, the upper portion of which is very sandy, indicating that a rise of land has again taken place in North Greenland. This rise of the land was very considerable, and again the Archeozoic and Algonkian strata were subject to erosion. Later on the land again subsided somewhat, and thick strata of conglomerate-sandstone and limestone were deposited. The entire series of strata bear distinct evidence of having been deposited in shallow water. They contain numerous fossils, which show that this series of strata corresponds to the American Clinton. The upper portion of the series consists af sandstone.

A mighty rise of land of about 400 meters now took place in North Greenland, since in many places we find valleys and rivers eroded to about this depth. Later on a sudden subsidence took place, and all these eroded depressions were filled with black shales containing several graptolites, as a rule Cyrtograptus predominates.

Towards the end of the Silurian time the land again rose very slowly. Upward, the graptolite shales become more sandy, and gradually pass into unfossiliferous sandstone. This elevation indicates the beginning of the Caledonian Folding.

To the great plateau of sediments may also be reckoned a small plateau in the eastern part of Peary Land. Here the strata consist of shales, limestone, and, at the top, sandstone, and have a total thickness of about 700 meters. The shales and limestones are very fossiliferous, and their fossils appear to be closely related to the Carboniferous faunas from East Greenland (Holm Land and Amdrup Land).

THE VARIOUS FAULTS IN THE CAPE YORK DISTRICT.

Looking at the map in fig. 4 it will be seen at once that a distinct fault runs from Cape Alexander to the interior of Inglefield Gulf, and this fault may also be traced in the interior of the fiords. North of this fault the gneiss forms a plateau at an altitude of about 800 meters. The ice cap extends almost to the boundary of this plateau which is traversed by steep valleys from which several glaciers pour out.

South of the fault we find sediments, and it may be stated with certainty that the throw of the fault along this line is about 800 meters. The fault appears again at the settlement Kangerdlugssuaq south of Inglefield Gulf, and may be traced to Olrik Bay and, following the direction of the fault, I have, although with some doubt, linked it with the fault in Dead Men's Fiord north of Cape York. East and north of this large fault no sediments occur.

In Prudhoe Land, especially to the west and parallel with this fault, is

another fault bounding an area of syenite that originally covered the gneiss and which may be traced in the interior of Mc Cormick Bay, where the syenite still rests upon the gneiss without being separated from it by faults

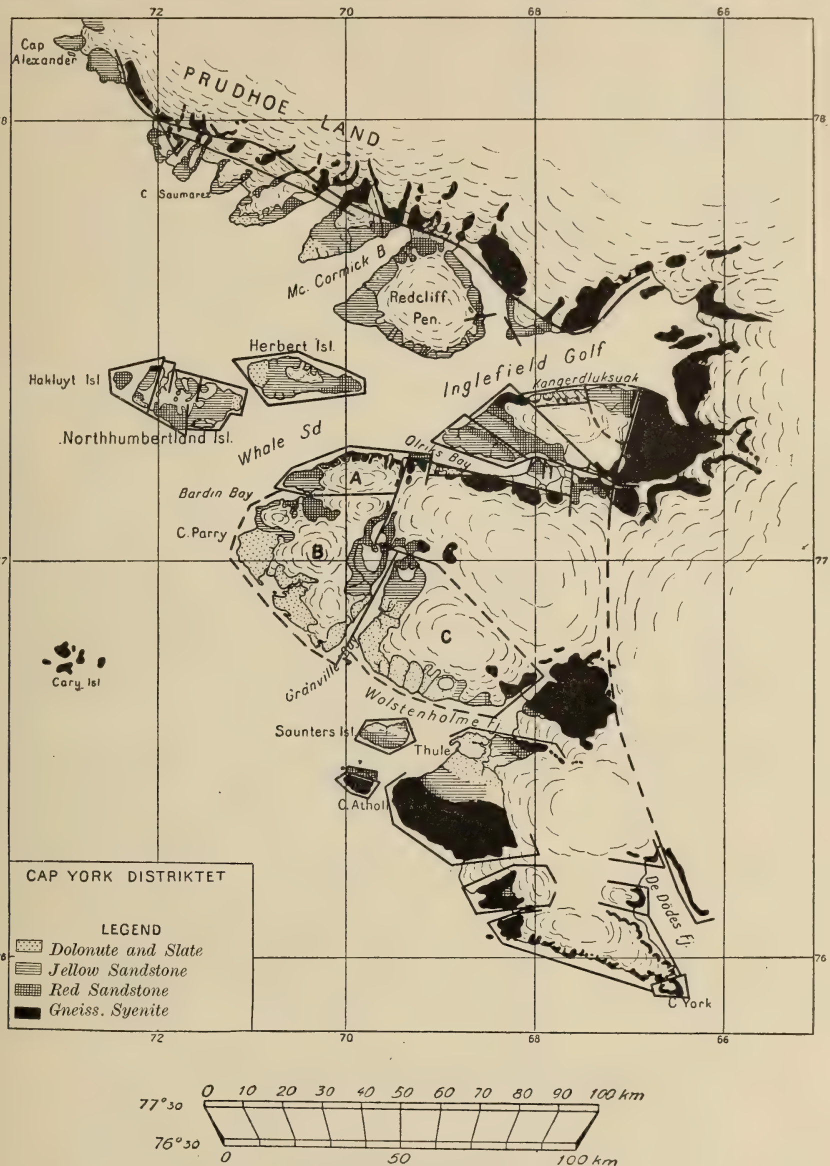

Fig. 4. The Cape York District. (Lauge Koch).

(see fig. 2). With regard to Prudhoe Land it may quite naturally be assumed that there is a second line of faults along the coast. The numerous small fiords extending to fault A and beyond as glacier-filled valleys into the gneiss area have, no doubt, been formed by faults, but we have no definite

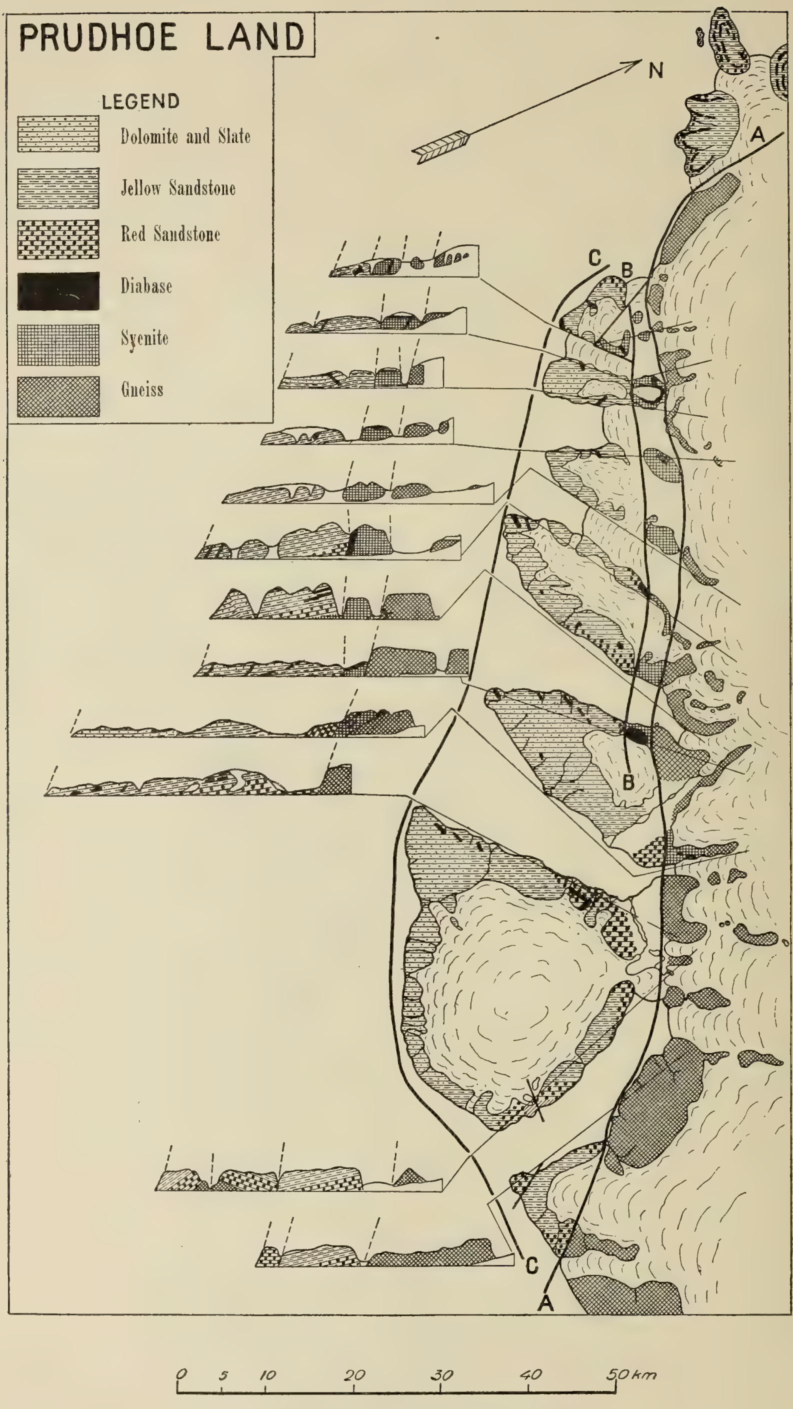

Fig. 5. Prudhoe Land. (Lauge Koch).

information. In fig. 2 the structure of Prudhoe Land is shown by the aid of a series of profiles.

The elements of the land between Inglefield Gulf and Olrik Fiord are easily determined. The faults in this region run southeast-northwest, the highest portions (in two places even gneiss) occurring to the northeast, and the strata dip southwestward like in Prudhoe Land. An exception, however, is formed by a small fault zone extending parallel to the coast. The gneiss here reaches an altitude of 500 meters, and is separated from a small area of black shales, i. e. the upper part of the sedimentary series, by a fault of a considerable throw.

The same is the case along the south coast of Olrik Fiord, where faults occur south of and parallel to the coast. From the map will be seen the great influence this has had on the shape of Olrik Fiord, which is due to faults.

A large system of faults extends northward from Granville Bay, which most likely has also been formed by faults, and farther on parallel with the fiord to Inglefield Gulf. Between Inglefield Gulf and Granville Bay this fault is marked by a valley, which is very much used by the Eskimos as a sledge route in autumn and spring when there is no ice round Cape Parry. From this glacier-filled valley, a valley extends to Bardin Bay, and the geological conditions near the coast show that this valley also has been formed by faults.

The whole peninsula between Whale Sound—Olrik Fiord and Wolstenholme Fiord consists of at least three blocks, A, B, and C, which all dip towards the southwest. The same is the case with Herbert Island, whose eastern headland is made up of the lower strata of the dark-red series of sandstone. When travelling westward along the coast one encounters successively younger strata.

Northumberland Island and Hakluyt Island are considerably more complicated. Northumberland Island like Herbert Island must no doubt be considered as a horst, which, however, is traversed by several faults running north—south. On the northern coast of this island the gneiss is again visible, and in continuation of this there is shallow water towards Hakluyt Island, which seems to indicate that the sea bottom consists of gneiss. The western portion of Northumberland Island and Hakluyt Island together form a fault zone dipping to the southwest. The central part of the island is traversed by numerous smaller faults, which, however, cannot be entered upon this map, but as a whole the strata dip towards the south. The eastern area lies almost horizontal, inclining slightly to the east.

The shores at the head of Wolstenholme Fiord are made up of gneiss below, then follow thin strata of dark-red and yellow sandstone overlain by dark slates, dipping upwards of 12 degrees southwestward. The same is the case with regard to the strata at Thule. South of this settlement a

low valley leads in to the ice cap and indicates the bottom of a flat syncline which can also be traced on Saunters Island.

Cape Atholl and the land east of this cape consists of gneiss, which continues into Wolstenholme Fiord and possibly farther on up to Cary Island. While thus the whole series of sediments in the Cape York district dip towards the southwest, i. e. almost parallel to the coast, there is a flat syncline in the southern part of Wolstenholme Fiord and south of this a gneiss horst. In the vicinity of Cape York no sediments occur, but it must be assumed that the peninsula west of Dead Men's Fiord is traversed by

Fig. 6. Cape York. (Lauge Koch).

faults, since the gneiss plateau at this place is composed of a system of blocks separated by glacier-filled valleys.

THE MORPHOLOGY OF THE CAPE YORK DISTRICT.

In fig. 6 is shown the extension of the Cape York district which, compared with other well-known areas, comprises about $^2/_3$ of West-Spitzbergen. The morphology of this region is, naturally, dependent to a very great extent on the various local fracture-lines. It has been mentioned above that fiords such as Olrik Fiord, Granville Bay, and maybe also the fiords in Prudhoe Land have been formed by faults. The coasts may also be referred to various classes or types, such as precipitous coasts composed of elevated gneiss or dark-red sandstone, or sloping coast mountains that, as a rule, are composed of yellow sandstone, or again flat shores with low land behind, composed of dark slates. In early literature the close resemblance of Saunters Island to Herbert Island, which consists of flat plateaus with steep walls, is already mentioned. Further Northumberland Island resembles Wolstenholme Fiord

to some extent, since these islands are traversed by faults, and Alpine scenery with local glaciers occurs. I never observed foldings in connection with faults, whereas flexures are of common occurrence.

The sediments are in several places penetrated by diabase dykes, and in several places there are large sills. It has been impossible to ascertain a direct correlation between the diabase and the faults. The diabase seems without exception to be older than the structural dislocations.

THE AGE OF THE FAULTS AND A COMPARISON WITH OTHER REGIONS.

In spite of zealous investigations I did not succeed in finding Cambrian strata in the Cape York district. On the whole there were only a few Pre-Cambrian sediments in connection with the faults. The strata themselves thus give no information as to the age of the faults. When comparing this region with others, it will be seen that Schei[1] found faults along Heureka Sound west of Ellesmere Land. According to the slight information on this matter, it may be expected that a closer examination will show a large fault zone in the regions west of the Cape York district. Holtedahl[2], who has worked up Schei's material and has given a short summary of his geological results, is of the opinion that these faults are younger than Trias and older than Tertiary.

When looking at the map of Ellesmere Land, it will be seen that in the western part of this land numerous small fiords, running northwards and southwards, occur, and on superficial view it looks as if these have been formed by faults, which, however, must have had a different strike than the faults in the Cape York district. Dr. Therkel Mathiassen, who as a participator in the Fifth Thule Expedition i 1923 made observations in the vicinity of Ponds Bay, has stated that in this region several faults that seem to strike north—south, i. e. in the same direction as the faults west of Ellesmere Land, occurred, but that they did not run parallel to the coast in Baffin Bay. Thus for the time being it cannot be ascertained, whether the two fault zones in the Cape York district and west of Ellesmere Land may be correlated.

It may also be assumed that the faults in the Cape York district are of Tertiary age. Disko Bay and Ũmánaq Fiord in West Greenland represent such a Tertiary fault zone. Also in East Greenland, in Spitzbergen, on the west coast of Norway (And Island), and on Iceland, as is well known, fault

[1] Schei, P. Vorläufiger Bericht über die geologischen Beobachtungen auf der zweiten norwegischen Polarexpedition. Leipzig 1903.

[2] Holtedahl, O. The Cambro-Ordovician Beds of Bache Peninsula. Report of the Second Norwegian Arctic Expedition in the "Fram" 1898—1902. Report No. 28. Kristiania 1913.

areas occur, where the strata have subsided towards the depths of the sea between Greenland and Norway (de Geer's Skandik). So long we have no further detailed information especially from Ellesmere Land, it may most naturally be assumed that the fault zone of the Cape York district has been formed simultaneously with the faults at Disko Bay—Ũmánaq Fiord, i. e. in the Tertiary Epoch, and have subsided towards the depths of Baffin Bay.

THE CALEDONIAN FOLDING.

The Caledonian Folding forms the north coast of Greenland from the eastern part of Peary Land to Hall Basin, and its continuation can be traced on Grinnell Land. In Greenland this folding reaches its maximum width in Peary Land, the northern part of which consists of mountains formed by folding. Farther westward the folding range grows narrower; its northern and central portions appear to have been eroded, since for instance i Nyeboe Land and Hall Land only the southernmost foldings occur. Neither does the folding seem to occur in its full width in Peary Land, but it must be assumed that the interior of Peary Land is made up of the central portion of this mountain range, since the mountains here are extremely high and wild, and most likely there is a nucleus here. Several blocks of granite on the north coast of Peary Land seem to originate from such a nucleus.

The western part of the folding range, particularly about Sherard Osborne Fiord and St. George Fiord, gives good information as to its structure. The mountain range is here penetrated by numerous valleys and fiords, and particularly in the spring, when the snow is melting, the various foldings may be distinctly seen, especially from a distance. It is possible to trace anticlines and synclines over long distances, thus the well-known mountains Mt. Farragut, Mt. Hornby, Dragefjæld, Mt. Punsch, Degree Hill, Rock Hill, and Mt. Hall form a great syncline. In a narrow belt south of this the strata are much folded, but farther on they grow more level.

The coasts on both sides of Victoria Fiord and farther on to Freuchen Land show a similar character. It is impossible to draw large continuous profiles of Peary Land, since the mountains are in several places covered by rock débris or by local glaciers. Altogether the Caledonian Folding is very prominent in the northern portion of Peary Land, possibly there are considerable overthrusts, at any rate there is a nucleus of Gneiss. Farther westward the folding is less prominent, and the sediments are only slightly metamorphosed. In the northern part of Hall Land even fossils occur, and it is possible to distinguish Clinton limestone from Cyrtograptus shales. The structure of Grinnell Land is similar to that of Hall Land, but towards the south the folding seems to disappear.

A SUMMARY OF THE GEOLOGICAL DEVELOPMENT IN NORTH GREENLAND.

As will be evident from the above, the gneiss plain in North Greenland was peneplained at a certain period. On this plain the Algonkian sediments were deposited. Afterwards an eruption took place, which made the surface very rugged, but later on it was again peneplained by erosion and the Lower and Middle Cambrian and the Ozarkian sediments were deposited.

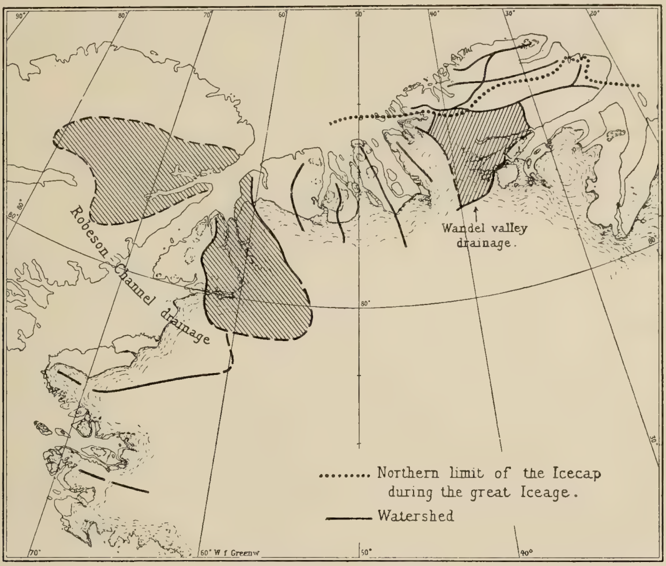

Fig. 7. The drainage of Robeson Channel and Wandel Valley. (Lauge Koch).

During Lower and Middle Ordovician very thick strata of sediments were deposited, since in this period no considerable earth-tremors took place. During the Silurian time, however, the land rose and subsided several times, sometimes it even rose above sea-level, and very remarkable topographical features were formed. In the Silurian strata there are evidences of a rise of the land directly preliminary to the Caledonian Folding. After this period of folding, the land again subsided, at any rate in the eastern part of Peary Land, and during the following gradual elevation of the sea bottom the series of Carboniferous strata were deposited.

The geological history of North Greenland after the deposition of the Carboniferous strata is unknown, since later strata are completely wanting. However, one is tempted to conjecture what may have been some of the main features in the subsequent history of the country. As already stated, not the slightest trace of faulting is found in the great plain of sediments, and hence we must conclude that the majority of the great fiords on the north

coast have resulted from erosion. The drainage west of Peary Land shows that the Caledonian mountain range is cut through in many places, and from this we can infer that the river erosion has kept pace with the folding action. Of particular importance is the region of Robeson Channel. In fig. 7 this drainage area is shaded, and its extent in Grant Land and in Greenland is shown as well; the figure furthermore shows that a land barrier must have existed in front of the present site of Humboldt Glacier, since a part of this area drains into Robeson Channel.

Kennedy Channel itself forms a direct continuation of the plain south of the Caledonian Folding, and this is why we must consider Kennedy Channel not as a sunken area, but as the result of river-erosion.

After the Carboniferous time a rise of land took place, so that North Greenland at the end of the Paleozoic time, and perhaps ever since, has been above sea-level. During this long time, river-erosion in a probably dry climate has formed the numerous canyons which now abound in North Greenland.

It has already been stated that the erosion area of Humboldt Glacier must be younger than Robeson Channel. It may be linked with the fault zone of the Cape York district, which is no doubt a mere continuation of the fault area that Schei discovered in Ellesmere Land, and whose age seems to lie between Trias and Tertiary. From the sediments in the Cape York district it is obvious that previous to the faulting they must have extended far westward as a plateau. Hence it must be assumed that no considerable river-erosion has taken place in the area of the present Kane Basin. Provided this fault zone of the Cape York district was formed in Mesozoic time, it must be assumed that the depression that now forms Smith Sound offered favourable conditions for a new erosion northward, where the land consisted of the slightly resistant Cambrian intraformational conglomerates.

Previously the sound from Smith Sound to Robeson Channel has been considered as a sunken area, but this is not correct. In the Paleozoic time the Caledonian Folding was penetrated by Robeson Channel, and a huge drainage area was formed both eastward and westward, which comprised also the northern part of Kennedy Channel, whose graptolite shales were almost eroded. In the Mesozoic time Smith Sound was formed by faulting, and in the course of a short time the Cambrian conglomerate strata were eroded and the present Kane Basin formed.

MORPHOLOGICAL SUMMARY.

In fig. 8 it is attempted to give an idea of the altitudes in North Greenland. At first sight the different elevations appear to be irregularly scattered, but a comparison of the relief map with the geological map shows that the altitudes are mainly due to the geological conditions.

Tracing the gneiss plain northward from Upernivik, it will be seen that, from an altitude of about 1000 meters, it gradually descends to Inglefield Land, when it disappears beneath the sea. This is why Inglefield Land lies at low levels. Corresponding features may be observed at the head of Danmark Fiord.

The Algonkian sediments of the Cape York district are traversed by numerous faults, which characterize the morphology throughout. In North-

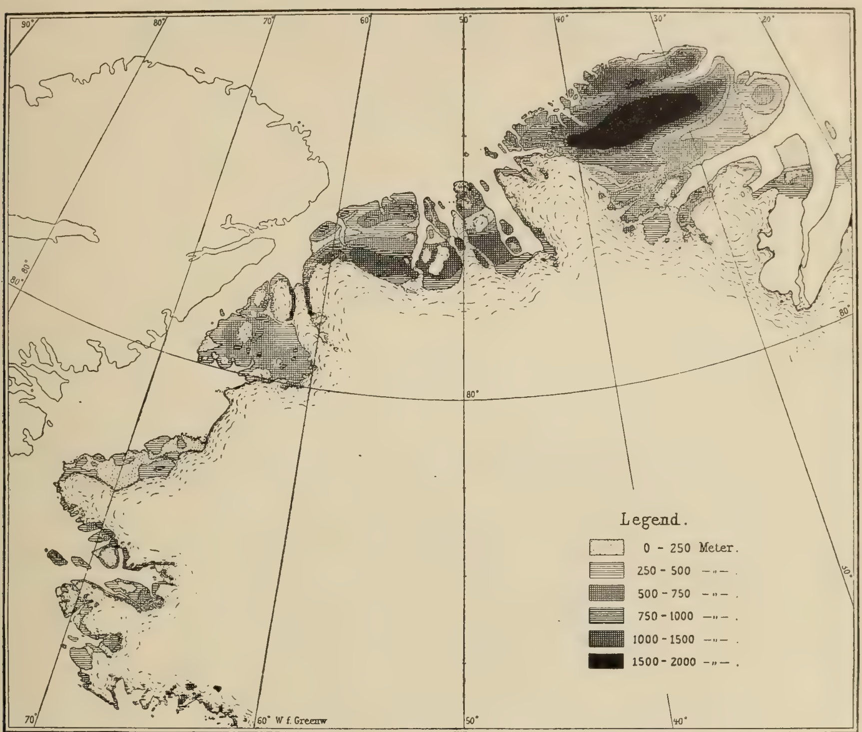

Fig. 8. Altitudes in North Greenland. (Lauge Koch).

east Greenland, however, these sediments form a vast plateau, which, from an elevation of 1200—1400 meters, gradually slopes towards the sea. This plateau comprises the entire Mylius Erichsen Land, Vildt Land, and Adam Biering Land.

The Cambrian strata, and particularly the several hundred meters thick Upper Cambrian intraformational conglomerates, are but slightly resistant. Formerly these strata extended across the area of the present Humboldt Glacier, and a fiord like Cass Fiord has been eroded through them. The present low plains of Daugaard-Jensen Land are no doubt also due to the erosion of these conglomerates.

The Lower and Middle Ordovician strata and the Clinton limestone are made up of very resistant rocks, and where such occur, from Kennedy

Channel to Peary Land, they form a plateau generally more than 1000 meters high, which, however, is cut through by the great North Greenland fiords. South of this plateau there lies a lower area, best seen between St. George Fiord and Victoria Fiord, since the Lower Ordovician strata, which here reach the surface, are softer than the younger strata occurring to the north.

The graptolite shales and the overlying coarse sandstone are very soft and can be traced as valleys and plains south of the Caledonian Folding from Hall Basin to Peary Land, the southern half of which is made up of these strata.

The Caledonian Folding attains its highest elevations in the northern part of Peary Land, where the strata are most folded and the mountain range widest, but also in the vicinity of Hall Basin there are peaks up to 1000 meters above sea-level.

The Carboniferous strata in the eastern part of Peary Land form a small elevated region surrounded by low plains with graptolite shales.

A SHORT DESCRIPTION OF THE VARIOUS REGIONS.

1. Melville Bay. Melville Bay is characterised by its glaciers, the coast consisting more of glacier termini than of land. Geographically, Melville Bay has its natural southern boundary at Holm Island and Wandel Land. North of this boundary the areas of land occur so sparsely that more than half of the edge of the ice cap reaches the sea, and in the spring the sea ice lies in an almost direct line from Wilcox Pt. to Cape York. To the north Melville Bay is bounded by the promontory of Cape York.

Everywhere in Melville Bay, the ice cap forms the background of the landscape, and in the southern part to Ice Cape the inland ice stands out as an unbroken horizontal line, and the few mountain peaks that rise above it, stand snow-bare and sharply outlined against the ice.

The scenery in the northern part of Melville Bay is of quite a different character. Here it looks as if a thin carpet of ice has been spread over a wild and ragged mountainous area. For long stretches in the bays near Cape York the ice even covers the outermost rocks, over which it reaches the sea. In some places near the coast one may form an idea of the details of the form of the mountains, but the rocks are only visible in precipitous mountain sides, where the ice-cover has generally burst. Farther inland large valleys and mountain regions may be distinguished, and not until a long way towards the interior of the ice cap are the mountains quite hidden by the ice.

It will be seen from the map that the ice cap from Wandel Sea to Cape York reaches the sea in about 70 places, and forms the coast over an area of about 300 kilometers. However, we cannot speak about 70 glaciers, since

several glacier termini are broken by skerries. For instance Steenstrup Glacier forms a unit from Red Head to Tugtuligssuaq, whereas the name of Hayes Glacier covers several glaciers.

There are seven glaciers more than 10 kilometers in width, viz. Steenstrup Glacier, Nansen Glacier, Kong Oscar Glacier, Peary Glacier, Mohn Glacier, John Ross Glacier, and Wulff Glacier. Particularly productive glaciers are Steenstrup Glacier, Nansen Glacier, and Kong Oscar Glacier. In 1920 more than 150 square kilometers of icebergs were discharged from these four glaciers, but this is presumably the production of several years. By far the greater number of the small glaciers that reach the sea, produce no icebergs, so more than half of the total glacier terminus must be assumed to be stationary and unproductive.

2. The Cape York District (from Cape York to Etah). This district comprises the fault zone, and for this reason exhibits a wealth of different types of scenery. Just north of Cape York are the Crimson Cliffs, low gneiss cliffs, down which flow 13 glaciers, as a rule through very short valleys. In another place of the district, in Whale Sound, the coast is of a similar character, consisting of gneiss rocks, down which come a great number of small glaciers. Also on the south coast of Inglefield Land numerous small glaciers move towards the sea.

Herbert Island and Saunters Island are of quite a different character, since they are made up of flat plateaus with almost vertical walls composed of horizontal sediments.

A third type is found north and east of the main fault zone, where gneissic mountains 800 meters high form a plateau, whose edges are, however, in several places penetrated by short valleys filled with rough glaciers.

Northumberland Island forms a speciel element, being originally a homogeneous plateau, which faulting, however, has divided into a series of blocks, only slightly displaced in regard to each other. Several of the faults form wide valleys which are now filled with glaciers.

A different type again is seen along the north coast of Wolstenholme Fiord, where the land consists of soft shales, containing several diabase dykes and diabase sills, forming crests and plateaus, but in places where they do not occur, the shales have been eroded, and vast plains are found along the coast.

These are only a few examples of the various types of scenery in North Greenland.

3. Inglefield Land. This area forms a plain, sloping gradually northward from an altitude of 200—500 meters. Almost everywhere the surface is level, only in the eastern part there are small elevations alternating with valleys. In the western part of the land the depressions in the surface of the gneiss have been filled with moraine masses, chiefly sand and gravel, and a few extremely plane areas can be found.

The coast is generally made up of almost vertical sedimental cliffs 200—300 meters high. The sediments extend some distance towards the interior of the land as isolated areas, only broken by the sloping gneiss plain, with which the fiords are floored everywhere.

4. Washington Land and Daugaard-Jensen Land consist of a plateau of sediments about 100 kilometers wide from the coast to the ice cap. The entire Daugaard-Jensen Land is a plain at an altitude of 300—600 meters with numerous wide and very flat depressions between small plateau-rocks, which only rise slightly above the surrounding area (fig. 5).

Altogether Washington Land is higher, rising from 400 meters to 800 meters to the north, and the surface is more broken. To the south a few wide valleys and isolated mountains occur, whereas the northern part of the land consists of level plateaus, partly covered with local ice caps. The surface is much marked by the geology of the land. The Cambrian and Lower Ordovician strata form rather low-lying plains, whereas the Clinton limestone and the Richmond limestone form plateaus upwards of 800 meters high.

5. Hall Land consists to the south of a range of plateau mountains 800—1000 meters high and traversed by wide valleys. North of this range is a level plain, lying only 100 meters above sea-level, the graptolite shales having been eroded here, and north of the plain is Polaris Promontory, made up of folded sediments and reaching an altitude of from 400 to about 700 meters.

This structure is characteristic of the landscape along the north coast of Greenland. Farthest south we find a plateau about 1000 meters high, consisting of the very hard limestone of the Richmond and the Clinton time. North of this are the Cyrtograptus strata which have been eroded in many places to low-lying plains, and farther northward is the Caledonian Folding. Thus Nyeboe Land is made up in this manner.

South of the high-lying Richmond—Clinton plateau in Warming Land we find a lower-lying plateau, corresponding to Daugaard-Jensen Land, and made up of the Ozarkian and Canadian strata, which are here denuded. Similar features are found in the southern part of Wulff Land, which is made up to the south of a plateau about 600 meters high, followed by a Clinton—Richmond plateau reaching a height of about 1000 meters, then by the graptolite plains and the sandstone at an altitude of about 300—500 meters, and finally comes the Caledonian Folding reaching an altitude of upwards of 1000 meters.

A similar structure is found in Nares Land (fig. 10).

6. Peary Land may be divided into two halves, a northern half north of about 83° n. lat., consisting of alps, the peaks of which reach an altitude of from 1000 to 2000 meters, very seldom more, and a southern plateau reaching its maximum altitude, about 500 meters, a short distance north

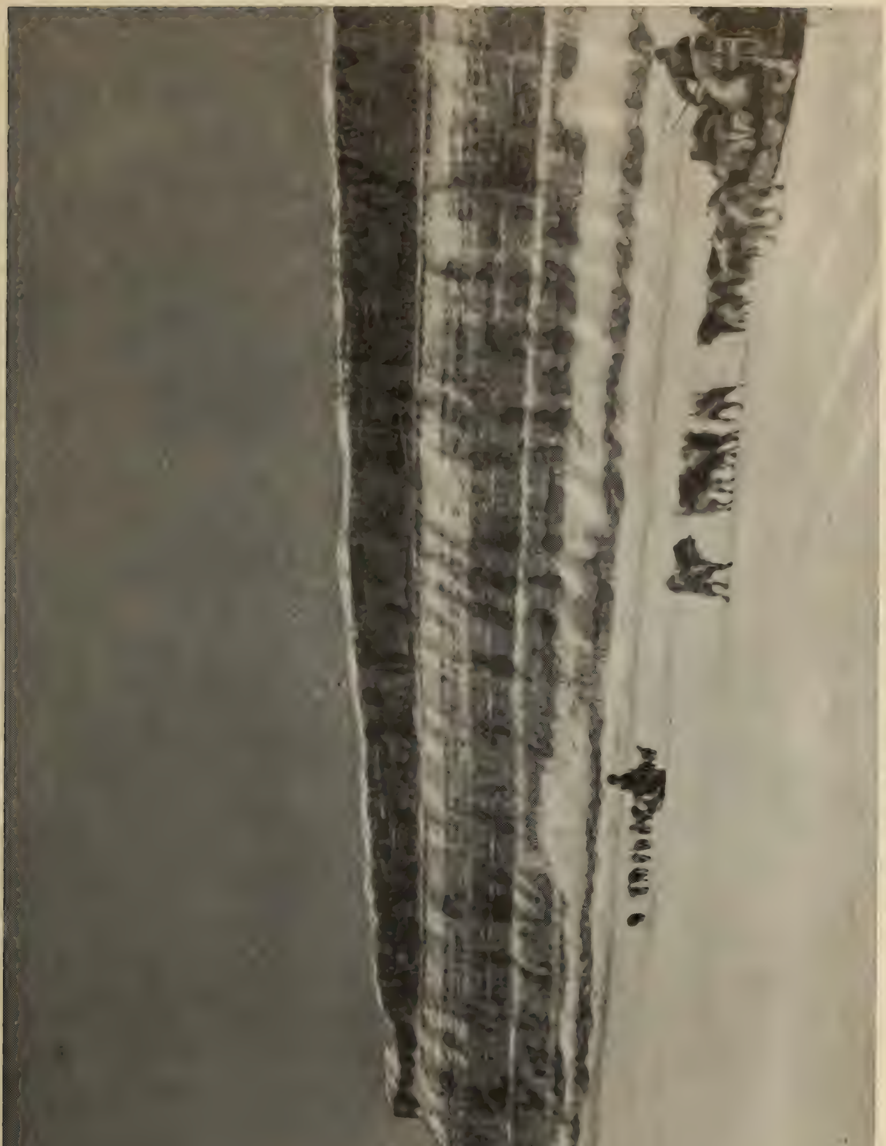

Fig. 9. Coast of Washington Land. (Th. Wulff).

of Brönlund Fiord, from whence it slopes northeastward towards a large drainage system south of the folding range that heads into Schley Fiord. Between Schley Fiord and Independence Fiord this plateau almost reaches sea-level, and here forms low-lying plains composed of graptolite shales. The small Carboniferous plateau east of this rises like an island above the graptolite plains.

7. Adam Biering Land, Vildt Land, Heilprin Land, and Mylius Erichsen

Fig. 10. Folded Rocks at Cape Payer. (Lauge Koch).

Land form a great plateau, cut through by deep valleys. To the south it has an altitude of about 1200 meters, from whence it slopes northeastward, and reaches sea-level in Brönlund Fiord and in Independence Fiord. The coasts on either side of the mouth of Hagen Fiord are made up of sills, only slightly elevated above sea-level and forming vast plains.

THE ICE CAP.

It has been mentioned above that the gneiss plain in North Greenland is unusually low-lying, and owing to this fact, the surface of the ice cap is also very low-lying. As a rule, the 2000-meter contour occurs 100—200 meters from the edge of the ice cap. The average distance between the 1000-meter contour and the 2000-meter contour is about 100 kilometers, generally more, since altogether the 1000-meter contour has a very irregular course. Behind the vast areas of land, the 1000-meter contour approaches

to the edge of the ice cap, but reaches it nowhere. Between the land areas behind the large fiords, the 1000-meter contour curves towards the interior, so that the glaciers here continue as depressions for long distances into the ice cap.

Above I have described Melville Bay and its glaciers. In the Cape York district the ice cap sends out a great many glaciers into the sea. However, none of them are particularly large, very large glaciers only occur farther northward. Humboldt Glacier, which covers more than one degree of latitude in width, is not only the widest glacier in Greenland, but in the entire northern hemisphere. Petermann Glacier north of this has a length of no less than about 200 kilometers from the 1000-meter contour to its terminus. Ryder Glacier has a similar length. Smaller glaciers are Steensby Glacier, Ostenfeld Glacier, Marie Louise Glacier, and Academy Glacier, although they all of them belong to the greatest glaciers that are known in the northern hemisphere.

North Greenland is unusually abundant in local glacier and firn areas. On Holm Island south of Melville Bay several small local glaciers of a pronounced alpine character occur. The area north of Cape York is a local ice cap, separated from the inland ice by a large depression, which is now filled by Pitugfik Glacier and Wulff Glacier. The entire peninsula between Wolstenholme Fiord and Whale Sound—Olrik Fiord is covered by local ice caps. Similar features are found on the peninsula between Olrik Fiord and Inglefield Gulf, and also on Red Cliff Peninsula and the region behind Cape Robertson. In Washington Land local ice caps occur, particularly on either side of Bessels Fiord. In Nyeboe Land, Heilprin Land, and Mylius Erichsen Land we also find small local ice caps. In the northern part of Peary Land there are numerous small local ice caps, but they generally occur as small firn areas in the valley glaciers.

FLOATING GLACIER ICE.

In fig. 7 it will be seen that on the north coast of Greenland there are four glaciers, great parts of which float on the sea. The largest is that of Petermann Fiord; including the depression, this glacier has a length of no less than 200 kilometers, of which the outermost 40 kilometers float on the sea. The floating part of the glacier is very thin, the terminus being only from two to five meters high. It may easily be understood why Petermann Fiord was assumed to be a channel opening towards the southeast for, standing at the mouth of the fiord and looking back into it only a few kilometers from the terminus of the glacier, you can see neither land nor glacier ice. The same is the case with regard to Ryder Glacier in Sherard Osborne Fiord, for the terminus of this glacier also is only a few meters high.

In the thick and old sea ice outside the glaciers in Nordenskiöld Fiord

and Independence Fiord (Academy Glacier) there are several detached icebergs. They suggest that at least several times in every century, and this is especially the case in Independence Fiord, there is open water that enables the icebergs to float away. The floating parts of these two glaciers are not composed of a homogeneous mass, as is the case in Petermann Fiord and

Fig. 21. Types of ice in the seas round North Greenland. (Lauge Koch).

Sherard Osborne Fiord, but only densely packed icebergs. In other words, they are formed by regeneration, crevasses having fissured the entire glacier before they begin floating. The area of these few floating glaciers of Northern Greenland is considerably less than that of the floating glaciers of the eastern coast.

THE QUARTERNARY EPOCH IN NORTH GREENLAND.

Let us return to the ice cap and consider its past history. What was its former extent? Was the whole of North Greenland covered with ice

during the maximum of the Glacial Epoch? The question has been discussed by Chamberlin and Salisbury and several others. My opinion is that no inconsiderable number of precipitous isolated mountains must have risen above the ice cap even at its thickest. Such areas, however, are of limited extent. All the rest of the surface was entirely covered with ice, as may be seen from the numerous erratic blocks that lie scattered everywhere, even

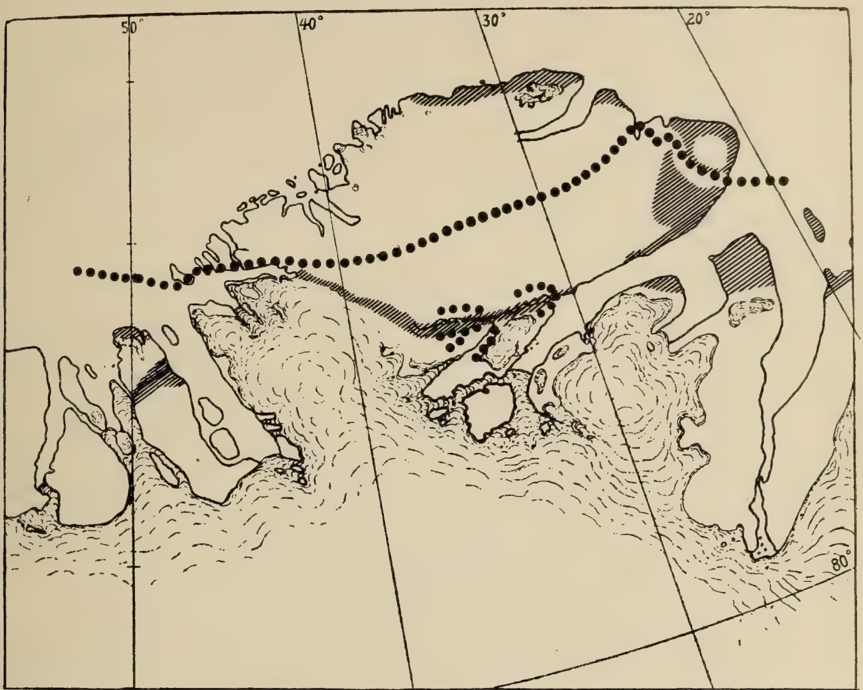

Fig. 12. Northern limit of the ice cap during the great Iceage. (Lauge Koch).
The dottet line indicates terminal moraines.
The shaded areas indicate raised postglacial marine layers.

on the plateaus along the northern coast. The mountain range that I observed along the northern coast of Greenland in 1917 changes its character, however, towards Peary Land. While the western part is plateau-like, farther eastward it exhibits alpine summits attaining heights of some 2000 meters. During my journey in 1921 I tried to find out if this mountain range had been covered by the ice during its maximum extension. When on my journey eastward I reached the northern coast of Peary Land proper, I found that the highly fossiliferous erratic blocks, common farther south, were absent, as were also the gneiss blocks from the interior of Greenland. Not until reaching Schley Fiord on the east coast of Peary Land did I encounter again the fossiliferous erratics. Furthermore, in the regions beyond the eastern point of Peary Land they were also lacking. It was not until I reached Cape Köbenhavn farther southward that I got the solution of the riddle.

From Cape Köbenhavn a vast belt of moraines runs west of the plateau that forms the eastern part of Peary Land, thence seaward into Schley Fiord, and thence westward along the southern edge of the mountain range (fig. 8). In the moraines were several blocks of rocks found farther south,

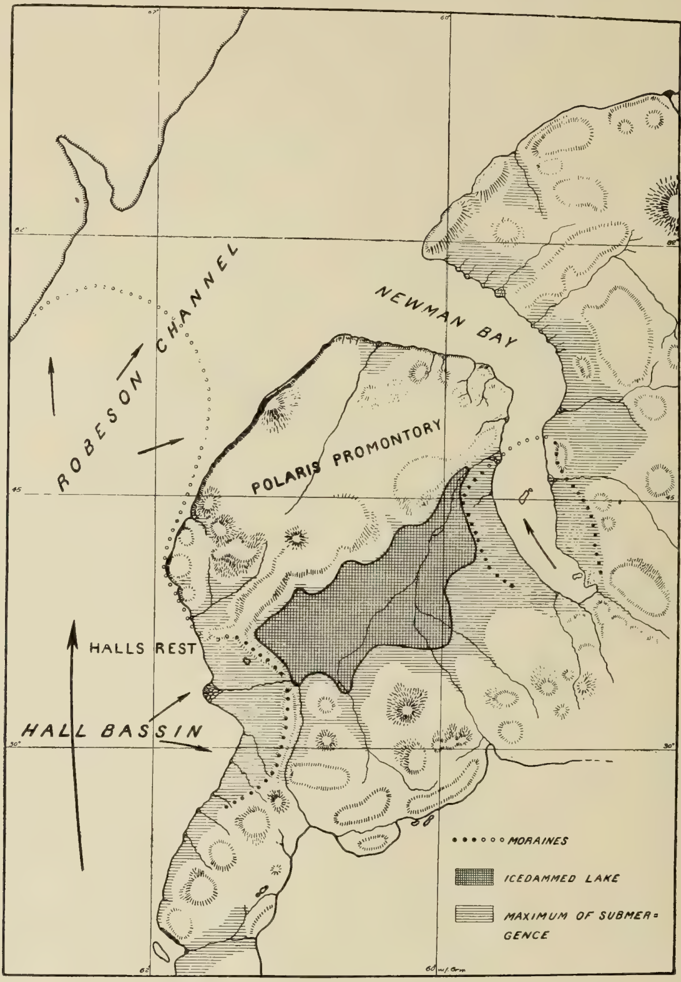

Fig. 13. Hall Land in late glacial times. (Lauge Koch).

whereas such blocks were entirely absent north and east of the moraines. In other words the belt of moraines indicates the maximum extension of the ice cap during the maximum of the Glacial Epoch.

The northern half of Peary Land has never been covered by the ice cap. In the first place this is due to topographical conditions. The southern part of Peary Land is a low plateau, whereas the northern part consists of alps more than 2000 meters high. However, these alps have once been covered by the local glaciers to a greater extent than is now the case; but I believe

that there must have been considerable ice-free regions even then. The dry climate that no doubt prevailed in these regions during the Glacial Epoch was very likely a concurrent cause.

The retreat of the ice at the termination of the Glacial Epoch was not continuous. In two places, at all events, moraines have been found that seem to show a halt in the retreat. I refer to morainic masses found in the depression formerly known as Peary Channel, which have had no slight influence on the water streams. This may be observed even more distinctly on Hall Land (fig. 9). The northern part of Hall Land must soon have become ice-free, and later also the level plain behind; but the two depressions on either side, namely Hall Basin—Robeson Channel and Newmann Bay, have constantly been filled with great glaciers. These glaciers in some degree extended over the level part of Hall Land; they must both have had flank moraines, between which a large ice-dammed lake must long have existed. Eventually it drained along the eastern moraine into the northern part of Newmann Bay. Whether the morainic systems in the "Peary Channel" depression and the moraine on Hall Land were contemporary cannot be settled as yet; only in these two places have I succeeded in ascertaining any considerable halt in the retreat of the ice.

After the maximum of the Glacial Epoch the land began to subside, and it is quite certain that during this subsidence, at all events, the ice cap was not more extensive than at present. This subsidence has been shown to have been 210 meters; above this limit there are in several places suggestions of shore lines; for the present, however, I dare not estimate it at more than 210 meters. That the ice cap, when the subsidence was at its maximum, was farther withdrawn than now is probable but not certain. On the other hand, it can be said for certain that during the maximum subsidence there was a great pressure of drift ice against the east coast of Peary Land. At a height of 200 meters I found in the soft clay the characteristic crushing that is very common along the present coast line, and which is due to the pressure of the drift ice. Subfossil shells are common in North Greenland, especially in the great fiords. Shells are found up to a height of 135 meters, and in the eastern part of Peary Land driftwood is found up to a height of 165 meters. Unfortunately all the species of animals found are forms which still live in the northernmost part of Greenland. In the interior of Independence Fiord there is a skeleton of a whale, and in the clay masses which Academy Glacier presses against the flank moraines 10 kilometers from its present terminus are found mussel shells. This would seem to indicate that Independence Fiord was once ice-free to a greater degree and that the glaciers in this fiord did not advance as far as at the present time, but it cannot be taken as proof of an improvement of the climate of long duration.

Afterwards the land again rose. Especially along the northern coast

of Greenland two distinct shore lines may be observed, one at a height of 105 meters and the other at about 65 meters. Farther southward, for instance in the Cape York district, the most typical shore line is about 50 to 55 meters high. Whether the movement was differential and the 50-meter line thus corresponds with the 65 meters on the north coast, cannot be definitely asserted but it is very probable. As far as can be observed, during the subsidence of the land the glaciers did not extent farther than at the present time. One isolated glacier on the north coast, however, is an exception, as it has advanced a kilometer across areas which were formerly covered by the sea.

THE LATEST PHASE.

It seems as if the inland ice since the maximum of the subsidence has varied little in North Greenland, but here as elsewhere there are naturally small oscillations in the various glaciers. Unfortunately we have hardly any earlier observations, and for this reason I shall here only mention the observations that I have made myself.

In August, 1916, I mapped the Moltke Glacier in the head of Wolstenholme Fiord. In April, 1923, I remeasured it. During the interim of 80 months this glacier had receded more than 2600 meters. A smaller glacier which I measured on Inglefield Land in 1917 and again in 1920 had advanced 400 meters, but a new observation in 1922 showed a retreat of 700 meters. This process, viz. advance until 1920 and afterwards retreat, seems to be typical of many of the glaciers in the Cape York district.

The only glacier I know in North Greenland that seems to have constantly advanced during many years is the famous Brother John Glacier. From Kane's and Hayes' descriptions and maps we know that at that time it did not reach Alida Lake; and even at the time of Nares' expedition a little of the land behind the lake was left, but since that time it has constantly advanced. In 1917 I saw it for the first time. In 1922 I measured it very carefully, and it appeared that during the past five years it had advanced considerably.

Photographs taken by Peary and his companions also bear witness as to the small changes in the ice cap glaciers of Northern Greenland. The ice cap here, as in Western Greenland, has varied very little from year to year.

THE PHYSIOGRAPHY OF EAST GREENLAND

BY

EINAR STORGAARD. M. Sc.

INTRODUCTION

As Greenland has the form of a trapeze, it falls natural to divide the outer land or coast fringe into West Greenland, corresponding to the long parallel side; North Greenland, corresponding to the one non-parallel side, which is approximately at right angles to the parallel ones; and East Greenland, consisting of two lines which are joined in an obtuse angle at Scoresby Sound.

More accurately defined East Greenland is then the ice-free coast, extending between Northeast Foreland (lat. 81° 24′ N.) towards the north and Lindenow Fiord (lat. 60° 27′ N.) towards the south.

The northern boundary is a matter of course, as Northeast Foreland is the most easterly point of Greenland (long. 11° 48′ W.), and the inland ice on the peninsula Crownprince Christian Land comes right down to the sea, thus making a natural division between East and North Greenland.

Greater difficulties are offered by the laying down of the southern line or the boundary towards West Greenland. When we have selected Lindenow Fiord, it is not only because the latter is the boundary of the Julianehaab District, but this administrative boundary is, as a matter of fact, based upon geographical conditions. The greatly incised country, consisting of peninsulas and islands south of this fiord, forms a natural continuation of the western part of Julianehaab District, and, therefore, Lindenow Fiord must be preferred to Cape Farewell, the most southerly point of Greenland.

However, from a physiogeographical point of view it would, perhaps, be equally correct to consider the whole of the Julianehaab District as making part of East Greenland, and to let the boundary between West and East Greenland pass either at Kobbermine Bay south of Ivigtût—the present westerly boundary of the district—or at Sermitsialik or Ikerssuaq (Brede Fiord) where the inland ice, like a lobe, shoots out towards the sea and, as at Northeast Foreland and in Melville Bay, forms a natural division

between the main parts of Greenland. In that case the old Österbygd would come to be situated in East Greenland, and so it seems as if the Norsemen really considered the boundary mentioned above as the line dividing the west and east coasts of Greenland.

When, nevertheless, we have chosen Lindenow Fiord, it is owing to practical and colonization considerations, as the Julianehaab District in the history of the colonization of Greenland, from the time of Egede to the present day, is reckoned as belonging to West Greenland. Furthermore, Lindenow Fiord from 1925 has been colonized by Greenlanders from Julianehaab (the Bendixen Expedition) and, finally, Julianehaab District has been dealt with in the preceding chapter, the "Pysiography of West Greenland."

East Greenland, then, extends so far towards the south, as there are large continuous masses of inland ice directly within the coast land, the country south of the 16 km broad isthmus between Lindenow and Tasermiut Fiords only containing local névés.

While the eastern boundary is easily determined by the Greenland Sea, Danmark Strait and the Atlantic, the definition of the western boundary offers greater difficulties. It is a matter of course that it must be the margin of the inland ice, but the situation of the latter is only known in broad outline, as few expeditions have had the opportunity of investigating the inhospitable east coast, the latter being nearly always cut off from the outer world by *Storis*, which comes drifting from the Arctic Sea between Asia and North America and keeps close to the shore. Also, the margin of the inland ice is not always in the same place, but oscillates, partly according to the seasons, partly in longer periods. There is, furthermore, the difficulty that there are considerable nunataq areas within the margin of the ice, the greatest being Queen Louise Land which is divided by two huge glaciers—L. Bistrup Glacier and Storströmmen—from Dove Bay and Germania Land (about lat. 77° N.), Duke of Orléans' Land and Lambert Land between Germania Land and Seventy-nine Fiord and Schweizer Land to the north of Angmagssalik. So much, however, is now known, *viz.* that the breadth varies between 0 and 300 km.

According to the indications given above East Greenland extends over 21 degrees of latitude, which corresponds with 2400 km, or as far as from the north of Scotland to the south of Spain. Its extent from west to east is 33 degrees of longitude.

In consequence of the many incisions, peninsulas and islands the coast line is far longer than it seems to appear from the figures given above, being, as the result of a survey undertaken by the Royal Hydrographic Office, estimated at 16,360 km.

The area of East Greenland is estimated at about 100,000 km^2—or

about $^1/_3$ of the ice-free regions—and one twenty-second of the total area of the huge island. Of European countries Portugal and Greece are almost of the same size, which is somewhat above twice the area of Denmark (44,000 km^2).

Even though the course of the coast line is fairly well known, this is by no means the case as regards the country.

With the exception of the region round Scoresby Sound—perhaps the

Fig. 1. Kingigtorssuaq. (Einar Storgaard).
In the foreground roches moutonnées with the station Angmagssalik. On the other side of the ice-filled Tasiussaq (King Oscar Harbour) Kingigtorssuaq with its alpine land-forms.

Svalbarde of the old Icelanders—it is properly speaking only during the present century and the three or four last decades of the 19th century that more accurate information of the east coast of Greenland and the country inside it has become available.

G. Holm and V. Garde, G. Amdrup, N. Hartz, Chr. Kruuse and O. Nordenskjöld, Ryder, Nathorst, Koldewey and Payer, Ejnar Mikkelsen, Mylius-Erichsen and I. P. Koch are the men who during the last five or six decades have done most towards mapping and investigating the east coast of Greenland. Finally, there is Lauge Koch, who in July 1926 left for East Greenland together with the Englishman, Tom Harris, and the Danish geologist, Alf. Rosenkrantz, for the purpose of investigating the distance between Scoresby Sound and Danmark Harbour (on Germania Land) which geologically offers so many points of interest.

But in spite of this work, for the greater part undertaken by Danish explorers, there are still long stretches which have either not at all, or

only once been traversed by scientists, and our knowledge of the physio-geographical conditions of the country is, therefore, in many respects very defective.

The ice-free land, *viz.* that which in this connection is understood by East Greenland is, as mentioned above, of very varying breadth. In many places the inland ice comes right down to the open sea, so that the country either disappears entirely or is reduced to isolated island-like rocks between the sea and the ice. This is the case in the boundary area between Frederik VI Coast and Christian IX Land (on either side of lat. 65° N.), in several places in Christian IX Land between Angmagssalik and Scoresby Sound, in Frederik VIII Land off Duke of Orléans Land, at Seventynine Fiord and, finally, at Northeast Foreland on Crownprince Christian Land.

But in other places the outer land attains a greater breadth than any-where else in Greenland. At Scoresby Sound—the largest fiord system in the world—the distance from the sea to the margin of the inland ice is about 300 km; at Franz Joseph Fiord 250 km. For comparison the greatest breadth of the outer land of West Greenland is about 180 km (Holsteins-borg).

Roughly speaking, the ice-free coast stretches are far narrower towards the south than towards the north, in which respect East Greenland forms a curious contrast to West Greenland, where the broad ice-free country is to be found in the south, while in the northern parts (Melville Bay) the ice comes straight down to the sea. This is *inter alia* explained by the fact that the highest parts of the inland ice in the south lie nearest the east coast, whereas in the north they are nearest the west.

The coast itself must rather be characterized as a "Skærgaard" or skerry fence. The coast line is extremely irregular with innumerable fiords and peninsulas, and with thousands and thousands of islands, islets and skerries of various sizes.

In the southern part—the gneiss area—the long and narrow fiords are, in the main, at right angles to the direction of the coast, being the outer, drowned parts of long valleys, which in many cases extend as far as the in-land ice and, therefore, in their inner parts are filled with glaciers shooting down into the valleys from the inland ice. Sometimes, however, the glaciers extend right into the fiords, where, in their turn, owing to the buoyancy of the water, icebergs are formed by the breaking off of the extreme parts of the glaciers. At these fiords the country generally forms steep bluffs towards the water which is proof that they were originally, *viz.* during the glacial period, entirely filled with glaciers and, therefore, assumed the glacial U-shape. When the coast in certain localities turns out to be less incised, this is perhaps merely due to the fact that the inner parts of the fiord are covered with inland ice, as the country in these places seems more elevated.

In the northern part of the east coast where sedimentary rocks are widely distributed, the fiords—as, for instance, Scoresby Sound, Davy Sound and Franz Joseph Fiord—branch in a very irregular manner, which circumstance is perhaps due to faulting.

There can hardly be any doubt that the east coast as a whole has received its peculiar character through faulting—Greenland is a horst—but when and how the faulting process has taken place, it is yet too early to decide.

Fig. 2. Angmagssalik Island. (Einar Storgaard).
Mountain land with roches moutonnées is the most widely distributed land-form in East Greenland. The picture shows the entrance to Tasiussaq (King Oscar Harbour).

According to the ideas prevalent at an earlier period, this was caused by the subsidence of the original country east of Greenland; according to the theory of Wegener it was because Greenland, which in former times was continuous with Europe, has, since the Tertiary age, been sliding westward.

The continental shelf is rather broad, and from the northern part of King Christian IX Land a submarine ridge passes in the direction of Iceland and farther to the Faroes and Scotland.

The greater part of East Greenland, like Greenland generally, consists of uplands, although there are also lowlands of a not quite inconsiderable extent.

But as contrasted with West Greenland the country is composed of a great variety of rocks, dating from the most different periods of the earth's history, from primeval times until our own day.

Least composite is the southern part of the east coast, as reckoned from

Scoresby Sound. It is highly reminiscent of West Greenland from Svartenhuk to Cape Farewell, though with the great topographical difference, which has already been mentioned above, that towards the west the outer land is broad, towards the east narrow. From Lindenow Fiord to Kangerdlugssuaq (lat. 67½° N.) the ground almost entirely consists of Precambrian rocks, gneiss and chrystalline schists, here and there with isolated occurrences of granites and other eruptive rocks, for instance at Angmagssalik. The latter are frequently, but by no means always, characterized by wild and jagged forms, as compared with the more rounded gneiss; the difference in forms being rather due to other causes which will be mentioned later on.

From Kangerdlugssuaq to Scoresby Sound—including the south side of the latter fiord—basalt occurs in beds interchanging with layers of tuff which date from the Tertiary period, the same layers which were found on Disko, Nûgssuaq and Svartenhuk in West Greenland. Also sedimentary layers from this period have been identified.

In West Greenland there is nothing corresponding to East Greenland north of Scoresby Sound, this area being composed of nearly all kinds of rocks from all periods and, geologically, perhaps the most interesting part of Greenland. In particular the area from lat. 70°—75° N. offers an abundant variety of different rocks from different periods.

An inner zone—nearest the inland ice—consists of gneiss, but outside it there are conglomerates, sandstone, slate, limestone, dolomite, etc. from the Cambro-Silurian, Devonian, Carboniferous, Triassic, Jurassic, Cretaceous and Tertiary periods. Though this area has not as yet been sufficiently investigated from a geological point of view—as a matter of fact this is the very task of the Lauge Koch Expedition mentioned above—it can, on the strength of the material already at hand, be said with a fair degree of certainty that the sediments are divided from each other, as well as from the Precambrian rock, by faults in the earth's crust, the main direction of which faults is north-south, or in other words very nearly parallel with the coast. The Paleozoic rocks most frequently occur in greatly dislocated or folded strata (Caledonian folding). Farthest out towards the sea, on projecting peninsulas and islands from Trail Island to Shannon Island, there are scattered occurrences of basalt and other eruptive Palæozoic rocks, which largely strengthens the theory of faults passing from north to south.

From King Wilhelm Land (within Shannon Island) to Northeast Foreland gneiss is once more the predominant rock, but at Queen Louise Land, on the north side of Germania Land, as well as on the south side of Crownprince Christian Land, sedimentary rocks occur.

Older—preglacial—loose earths occur practically nowhere; during the glacial period they have been worn away and carried out to sea, and Quartenary formations only play a secondary part.

Stratified diluvial deposits occur on Jameson Land (Scoresby Sound)

Fig. 3. Mörke Fiord in Germania Land. (I. P. Koch).
The plateau land-forms are widely distributed in East Greenland. The picture shows the 800 m deep cleft of Mörke Fiord seen from Danmark Monument.

where there is also drift-sand, while moraine formations are almost entirely lacking or only attain an insignificant thickness in the shape of lesser terminal moraines across a valley.

As the article on the "Physiography of West Greenland" contains a detailed account of the greater and smaller resistance of rocks against the various destructive agencies, *viz.* splitting, weathering, decomposition and the erosion of wind and ice, we will not, in this place, occupy ourselves with this point, it being in the main the same forces which have been at work in the configuration of East Greenland, and so the reader is referred to the chapters of the above article which deal with this special problem.

The land-forms of the ice-free country are rather varying, as there are plateaux—both low-lying and elevated—as well as mountain land, partly with rounded, partly with alpine forms. The distribution of these various types frequently seems very irregular, but this is explained by the fact that it is only a narrow strip of a large country which is known, while the remainder is entirely buried below ice.

The greater part of East Greenland is mountain land, as not only the Precambrian rock (gneiss and granite) but also many of the sedimentary rocks—particularly those which are folded—are shaped as mountain land.

Most widely distributed in East Greenland is mountain land with the more rounded forms—the roches moutonnées or moutounéed land-forms—which are due to the planing agency of the ice during the glacial epoch, when the inland ice covered the whole of the country, with the exception of the highest peaks. In its main forms this mountain country is greatly stamped by glacial erosion: the rocks are bare, glaciated and smoothly polished, the valleys have a clearly defined U-shape, and there are numerous cirques along the mountain slopes. But from many details it appears that this country, after the ice-age, has been subject to the agency of the normal (subaerial) erosion, which *inter alia* manifests itself in the fact that the rocks may be more or less split and decomposed. There are all sorts of transitions between the so-called "Rumpfgebirge," which are greatly intersected by river valleys and the usual type where the individual mountains are more irregularly distributed.

Besides the roches moutonnées there are also alpine landscapes with high, jagged peaks or dentate crests, which lend a wild and impressive appearance to the coast. The alpine peak-forms generally only occur on the rocks, which during the glacial period projected above the ice and which, consequently, were throughout exposed to the agency of weathering (nivation). The environs of Angmagssalik, consisting of gneiss and granite, present a splendid alpine landscape with snow-clad parts between the peaks and glaciers, which shoot down into the interjacent valleys, the latter therefore generally being U-shaped. But forms of equal boldness also occur farther north in the area of the sedimentary rocks, most beautiful perhaps at Franz Joseph Fiord and Davy Sound (se figs. 21 and 22).

Rather widely distributed are also the plateau landscapes, and this is principally due to the considerable extent of the basalt areas. These areas

consist of almost horizontal layers of basalt which, when viewed from the surface, look like large, level plains, while from the sea they frequently present the appearance of mountains, as the margins are split up by valleys which cut deeply into the country; indeed, in certain places the landscape may look quite alpine, the walls dividing the cirques having disappeared or been transformed into sharp comb-ridges. This is seen in several places on Christian IX Land. In the neighbourhood of Scoresby Sound there are plateau lands formed of sediments; they are less extensive than the basalt

Fig. 4. Drift-sand on Jameson Land. (Chr. Kruuse).
Drift-sand with Salix and Festuca rubra. In the foreground the dune is broken down, showing dark streaks of a former vegetation cover.

plateaux, but like the latter they are sometimes greatly incised. Also Precambrian rock areas frequently have a plateau-like surface.

Generally speaking East Greenland is higher than West Greenland, and the mountains often rise to great altitudes directly within the coast, thus making the effect still more impressive. At one time Mt. Petermann (Petermann Spitze) within Franz Joseph Fiord was considered the highest point of Greenland. It was discovered by the German North Polar Expedition and by the latter measured at 3480 m, but according to Nathorst this figure was too high by several hundred metres, as it was thought to be situated much farther inland than it really is, and Nathorst estimates that it is at most 2800 m, *viz.* the height which previously undertaken surveys assign to Mt. Forel (north of Angmagssalik). Quervain, however, estimates the height of Mt. Forel at 3440 m, and if this proves to be correct, this mountain must be considered the highest point of Greenland. At

Blosseville Coast Mt. Rigny is situated (2385 m), and besides these points there are still many which attain a height of more than 2000 m.

In this connection it should be mentioned that, on the strength of the sparse information at hand, Lauge Koch has drawn a profile of the height of the gneiss surface on the east coast of Greenland, bringing out the same peculiarity as appeared on the west coast. From the north coast where the gneiss surface gradually sinks below the surface of the sea, it rises to about 2000 m in lat. 70° N. and then again suddenly falls to the surface of the sea,

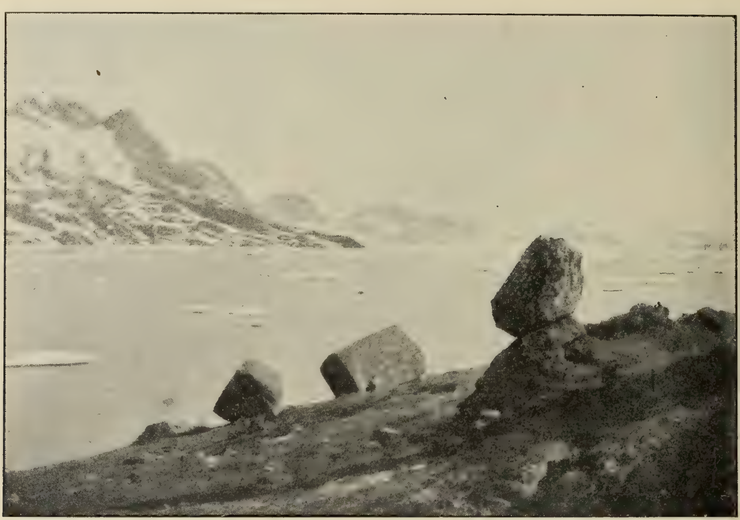

Fig. 5. The boulders at Kingaq. (W. Thalbitzer).
Erratic boulders on the shore of Angmagssalik Fiord.

once more increasing towards the south to about the same level as at Scoresby Sound. It is in the very neighbourhood of lat. 70° N. that the large occurrences of basalt are found, in West Greenland as well as in East Greenland, and therefore, undoubtedly with good justice, Lauge Koch is of the opinion that an enormous displacement has taken place in Central Greenland, and along the fault line the basalt has cropped out. From the basalt area south of Scoresby Sound a submarine ridge, as mentioned above, extends towards the basaltic country Iceland, and farther to the Faroes and Scotland, where basalt also occurs.

Besides the huge inland ice which forms the western boundary of the area in question, and which in many places extends right down to the fiords or even to the open sea, there are on plateaux and in depressions between mountains on the many peninsulas and islands of which Greenland consists, isolated glaciers, local névé areas, the greater part of the precipitation taking the form of snow, accumulating and transforming into ice, which then, in its turn, is set into motion downwards. As to the local névés it is comparatively rare for the glaciers deriving therefrom to reach right down to

the surface of the sea, as they are generally too small to attain this result.

The most considerable local névés occur in the area between Scoresby Sound and lat. 75° N. where the ice-free land attains it greatest breadth; here nearly all of the slightly larger island and peninsulas contain névés.

The greatly incised land, split up into peninsulas and islands, naturally does not lend itself to the formation of large river systems, although this does not mean that there are no water courses. Innumerable small rivers

Fig. 6. Kingigtit. (Einar Storgaard).
Seen from the south-east Kingigtit reminds one of a »sugarloaf«, but it is in reality an impressive dentate crest. It is situated on the eastern side of the intrance to the fiord of Sermilik (Egede and Rothe Fiord).

and rivulets furrow the narrow strip of land between the inland ice and the sea or the fiords. The amount of water is often considerable, and anyone who has travelled in these parts knows how difficult it may be to get across these water courses, which at times force him to make long detours. Most of the rivers are fed by the inland ice, by local névés or by snow accumulated during the winter.

The rivers are distinctly young; in foaming cascades, waterfalls and rapids they rush from the plateau down towards the sea; areas with a sharp slope interchange with places where the slope is extremely slight, or with elongated lakes, which may either have been formed by the excavating agency of the ice, when in the glacial period it passed over the now ice-free land, or by the depositing of small walls of terminal moraines.

For the population the rivers are of great importance, as they supply the water necessary for the use of the household. In the selection of dwelling

places regard must, consequently, be had to whether there is, in the neighbourhood, a sufficiently large water course.

As there is only a narrow strip of land which is ice-free and therefore known, it may frequently seem as if the different types of land-forms occur in a perfectly irregular manner, and it is consequently difficult to classify them into greater morphological unities.

Nevertheless, an attempt will be made in the following to present some

Fig. 7. Mountain landscape on Angmagssalik Island. (Einar Storgaard). The picture is seen from the 600 m high Sömandsfjæld southwest of the Angmagssalik station.

natural geographical regions. For the bounding of the latter we have, besides the variety of the rocks and their geographic distribution, made use of large incisions, the trend of the coast-line, the occurrence of larger and smaller groups of islands and peninsulas as well as the advance of the inland ice towards the sea.

By this means we then arrive at the following natural geographical regions:

1. Frederik VI Coast (from Lindenow Fiord to lat. 65½° N.).
2. The Southern Christian IX Land extending as far as Kangerdlugssuaq (lat. 68° N.).
3. The Northern Christian IX Land, the basalt area from Kangerdlugssuaq to Scoresby Sound, including the south side of that fiord.
4. The Scoresby Sound Archipelago.
5. Jameson Land.
6. Liverpool Land.

7. King Oscar Archipelago (the islands and peninsulas round Davy Sound and Franz Joseph Fiord).
8. Hudson Land—King Wilhelm Land (the stretch between Mackenzie Bay on Hudson Land and Dove Bay).
9. Germania Land.
10. Queen Louise Land.
11. The Southern Frederik VIII Land (the islands and nunataqs between Germania Land and Seventy-nine Fiord).
12. The Northern Frederik VIII Land.

The following discription is in many cases a direct excerpt from the works of previous writers, principally: *On the Geology and Physical Geography of East Greenland* by Otto Nordenskjöld (M. o. Gr. vol. XXVIII), and *Survey of Northeast Greenland* by I. P. Koch (M. o. Gr. vol. XLVI).

FREDERIK VI COAST.

The most southerly part of the east coast of Greenland was given the name of Frederik VI Coast by Graah, who travelled there from 1829 to 1830. It extends from the 60 km long Lindenow Fiord (lat. 60° 27′ N.) to the large ice-fiord Ikersuaq (lat. 65½° N.) slightly north of Dannebrog Island.

The outer land is comparatively narrow as far as Kangerdlugssuaq (Bernstorff Fiord, lat. 63° 40′ N.) and then, farther north, disappears almost entirely, the inland ice in this place coming right down to the coast. As a reason why the outer land in this place is so narrow, it has been mentioned in the general introduction that the highest altitude of the inland ice in South Greenland occurs nearer to the east coast than to the west, and to this it should further be added that the land in the southern part of the east coast is comparatively high, which causes a greater distribution of ice.

The main direction of the coast is north to south and it is incised by a number of narrow fiords, almost at right angles to the coast and divided by large peninsulas, nearly all covered by lobes from the inland ice or by local névés.

The largest of the fiords to the interiors of which the inland ice generally extends in the shape of more or less productive glaciers, are Danell Fiord, Kangerdluluk, Anoritôq, Napassorssuaq, Kangerdlugssuatsiaq (Mogens Heinesen Fiord), Tingmiarmiut, the outer half of which forms a large fiord system centring round the Tingmiarmiut Island, Ũmánaq Fiord (Sehested Fiord) with the largely incised Ũmánaq or Griffenfeld Island, situated on the outside, the 50 km long Inugssuarmiut, which together with the equally long Akorningnap Kangerdlua encloses the elongated island Skjoldungen, and finally Bernstorff Fiord. Along the latter part of this stretch, from

Tingmiarmiut, the outer land is comparatively broad, up to 60 km, and local névé areas are of rarer occurrence.

Along the distance north of Bernstorff Fiord, where the inland ice, as mentioned above, reaches right down to the coast, only leaving isolated promontories and nunataqs and the islands situated off the coast line, three large bays cut into the country. Of these the southern one, Umîvik, is the best known, as it was from here that Nansen in 1888 ascended the inland

Fig. 8. Iluileq (60° 52' n. B.). (H. Knutsen).
In the foreground roches moutonnées with characteristic mountains.
Seen from Qasingartôq.

ice in order to undertake the first journey across Greenland. The next bay is Pikiutdleq (Kjøge Bay), and farthest north lies Ikerssuaq. Off the south side of the latter lies Dannebrog Island (Qivdlaq), Graah's most northerly point on his journey (1829—30).

Practically the whole of this area consists of gneiss, with secondary layers of other chrystalline schists as well as of granite, syenite and other eruptives, which at various periods have intruded into the older Precambrian layers and hardened there in the shape of more or less irregular masses.

The land-forms are generally alpine, and as the mountains attain considerable heights—2000 m and more in the very neighbourhood of the coast—the scenery is of a wild grandeur and majesty (fig. 9). That the alpine forms predominate to such an extent is perhaps due to the fact that the inland ice in southern Greenland never has and never has had—not even within the glacial period —such a thickness as to be able to cover the whole land, for which reason the highest peaks always stand out as nunataqs and have been

exposed to the agency of nivation and decomposition. That also the nature of the rock plays a part in this respect appears from the fact that the boldest forms occur within the granite areas, the granite possessing greater resistance against weathering than the gneiss. On the other hand, the less elevated parts bear the distinct stamp of the smoothing agency of the ice. In the narrow fiords, surrounded by splendid and impressive mountains with ice-clad and snow-covered summits, the glaciers of the inland ice de-

Fig. 9. Tingmiarmiut Island. (H. Knutsen).
In the southern part of Frederik VI Coast the alpine land-forms predominate, and the mountains attain considerable heights — 2000 m and more — near the coast. The highest peaks have never been covered with ice.

bouch and, together with them, numerous small glaciers from the local névés. One of the best known of these is Puissortoq, of ill repute and projecting from the very inland ice, which in this place comes right down to the sea. The most productive glaciers occur in the most northerly part of the area, where the inland ice, with a broad front, comes down to the sea.

THE SOUTHERN CHRISTIAN IX LAND.

The Southern Christian IX Land extends between the two huge ice-fiords Ikerssuaq (lat. 65½° N.) and Kangerdlugssuaq (lat. 68° N.).

From Ikerssuaq in the south to Cape Dan (Naujánguit) on the island Qulusuq the main direction of the coast is east to west, while from there it

trends towards the north-east. Round the Angmagssalik settlement the ice-free land is of a considerable breadth which, north of lat. 66½° N., decreases greatly.

The rocks within the area of the Southern Christian IX Land mainly consist of gneiss and other chrystalline schists, such as amfibolite and mica; here eruptives occur in far greater amounts than on Frederik VI Coast, first and foremost granite which, owing to its greater resistance against weathering and decomposition, forms very distinctive mountains, bounded by steep, in some places even perpendicular, faults with rift valleys. Of loose earths sand and gravel are the most common, while clay only occurs in the interior of fiords, which do not contain calving glaciers, as, for instance, Ikerasaussaq and Tunoq and on the lee side of islands. The deposits of gravel are most widely distributed; drift-sand is found to the lee of rocks on the southerly or easterly sides of the latter, where it is deposited in winter together with snow. A raised sea bottom occurs in several places, but it is nearly always formed of sea gravel, foreshores and rounded moraine material which are the visible signs of post-glacial upheaval.

The area of the Southern Christian IX Land is, upon the whole, full of rocks and mountains, containing in its higher parts pronouncedly alpine forms. The common height of mountains is 1000 m, but numerous peaks attain a height of 1500 m, and the highest point in the outer land, Mt. Ingolf, even 2300 m.

What further emphasizes the majestic character of the land is that these mountainous tracts rise directly from the level of the sea and fiord. The slopes are uncommonly steep; perpendicular or nearly perpendicular walls of 500 to 800 m in height are common, and the highest portions of the mountains generally have a slope of more than 60° and end in wildly jagged, dentate points (combs), which in solemn grandeur are not inferior to the boldest alpine landscapes of Switzerland. These uplands have in all probability never been covered by the inland ice, not even when the latter was most widely distributed. On the other hand, the excavating and smoothing agency of the ice appears most clearly in the lower parts where the moutonneéd forms are common, and where valleys have the glacial U-shape, the inclination of the mountain sides being here 10 to 30°. Only where they are traversed by old plutonic rocks, are there outstanding protuberances and walls. The boundary line of the two different land-forms is at 700 to 800 m, approximately.

In the mountain sides there are frequently incised cirques which still contain local glaciers, but, in spite of their considerable number, the higher parts are only to a very small extent covered with snow, and large névé areas are not known from the Angmagssalik District.

The lowland is of very small extent. Lowland, in the proper sense of the

word—under 200 m—is only to be found in the very neighbourhood of the trade and mission station, on Cape Dan Island, at Qíngorssuaq, Tunoq, at the head of Ikerasaussaq and on the smaller islands as Íkáteq, the lowlands being most frequently very broken and uneven hilly country. Low plains hardly occur at all.

The coast is greatly incised. Numerous and widely ramified fiords cut deeply into the land, splitting it up into a maze of peninsulas and islands, divided by narrow sounds.

Fig. 10. Kingigtorssuaq (1000 m). (Einar Storgaard).
Kingigtorssuaq — on Angmagssalik Island — shows a typical alpine landscape with wildly jagged, dentate peaks. The rocks consist largely of granite, which has a greater resistance against weathering and decomposition than gneiss.

The southerly Ikerssuaq is considered the most dangerous icefiord in the whole of the southern part of the east coast of Greenland, being filled with icebergs of all sizes and with *Storis* from the sea. Along the stretch from Ikerssuaq to Sermilik there are several large incisions with many islands which are comparatively low and have rounded forms. Farthest west there is only a narrow strip of land between the ice of the main land and the sea, but farthest east the inland ice recedes from the coast, being supplanted by lofty, in part wildly jagged mountains.

To the east of the 1000 m high promontory Qârusuerneq, the large icefiord Sermilik (Egede and Rothe Fiord) extends 100 km into the country. In its outer part it is 10 km broad, but it becomes broader towards the interior and on either side; particularly on the west there are large incisions,

as, for instance, Johan Petersen Bay, where in 1912 de Quervain descended from the inland ice. Farthest up Sermilik divides into an easterly and a westerly arm, into which—as is the case with most incisions—glaciers from the inland ice debouch.

The outer part of the west side of the fiord is lofty and mountainous with peaks of 1000 to 1200 m, but farther in the mountains become lower (600 m) and rounded. North-east of the head of Sermilik there are nunataq areas, *viz.* Schweizer Land with Mt. Forel, which with its 3440 m is in all probability the highest mountain of Greenland. Along the latter part of the east side of Sermilik the large island Angmagssalik is situated, being divided from the mainland by the sound Ikerasagssuaq. The west side of the island has only few incisions. Off the south-western part there is a group of small islands, such as Íkáteq.

The island Angmagssalik is very mountainous. The mountains, the highest altitudes of which (about 1000 m) are to be found nearest the coast, largely consist of granite. The interior of the island contains three large lakes, one above the other, and rising from south to north. The lakes communicate by means of rivers, forming several fine waterfalls and at last debouching into Tasiussaq Bay, which cuts into the country from the south. Numerous small rivers occur among the mountains, most of them draining into the large lakes.

While the west and the north-east coast only have few incisions there are a greater number of bays on the south and east side. The most westerly of these is the bay at Naujatalik, towards the west bounded by the mountain Kingigtit which, when viewed from the south-east, by its conical shape reminds one of a "sugarloaf", but which in reality is an impressive dentate crest (fig. 6).

The largest of the incisions of the south side is the above-mentioned Tasiussaq (King Oscar Harbour), near which the mission and trade station of Angmagssalik was established in 1894, and the founder of this settlement, Gustav Holm, could hardly have selected a better situation. Tasiussaq, which lies to the east of Orssuluviaq, the south point of the island, is 7½ km long and at its broadest 5 km broad. The surroundings are extremely grand. From the 600 m high Sømandsfjeld, south-west of the station, there is a view which is hardly inferior to any alpine scenery (fig. 7). Towards the north and north-east the 2300 m high Mt. Ingolf is visible far out on the horizon, together with the jagged and snow-covered uplands, Kingigtorssuaq and Qordlortoq, quite close to the other side of the bay, and Præstefjeld (Ãmagâq) due north of the station; towards the southwest the coast is dimly visible all the way down to Umîvik and Graah Island, towards the east as far as Cape Dan on the island Qulusuq, and towards the west as far as the inland ice on the other side of Sermilik Fiord.

Tasiussaq is the most fertile place in the whole of the district, with greatly varying natural conditions and, above all, with more lowlands than any other part of the coast. Within the immediate environs of this bay we find nearly all the flowering plants occurring in the district.

Of the bays of the east coast special mention should be made of Tasiussarssuit and Tasiussaq. On an isthmus to the north of the former Holm's Women's Boat-Expedition spent the winter 1884—85.

Fig. 11. Angmagssalik. (Einar Storgaard).
In the foreground around the little harbour of the mission and trade station roches moutonnées, in the background alpine land-forms.

East of Angmagssalik Island Angmagssalik Fiord cuts 65 km into the country, first in a northerly, afterwards in a north-westerly direction. The outer part of the fiord is bounded by islands, both towards the west and east; in the west Angmagssalik Island, which has been mentioned above, and in the east Qulusuq with the promontory Cape Dan, Umîvik and others. Through Ikerasagssuaq the fiord communicates with Sermilik, through Ikerasak and Tunoq with Sermiligâq. The inner part of the fiord as well as the long and narrow Ikerasaussaq closely approaches Sermilik, from which the former is divided by a valley filled with lakes, which is surrounded by grand and impressive mountain scenery with several isolated peaks of 2000 m, among others Kilikitaq. Numerous glaciers wind between the mountains, but do not reach all the way down to the fiord, and the outflow from them accumulates in a greatly branching river, which flows through a large and sandy river plain. In its lower parts the whole of this region, which is

called Qíngorssuaq, is distinguished by very luxuriant vegetation, containing willow copses one metre in height and quans, which on an average attain a height of 0.9 m.

On the western side of Angmagssalik Fiord—north of Ikerasaussak—Qingaq or Angmagssivik is situated. The whole district derives its name

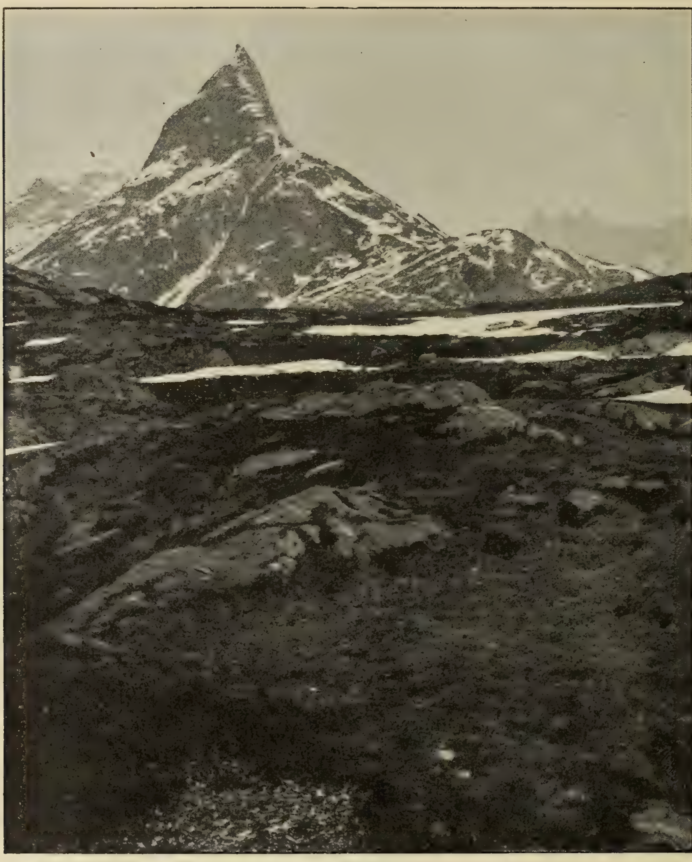

Fig. 12. Mt. Misugtoq (Quaniartivin) (Chr. Kruuse).
This 1170 m high mountain — the Matterhorn of Greenland — lies opposite to the Qingaq in the interior of Angmagssalik Fiord.

from this place, the inhabitants of the district assembling here in the months of May and June for the fishing of angmagsset, or caplin (*Mallotus villosus*). Opposite to it, on the east side of the fiord, lies the 1170 m high mountain Misugtoq or Quaniartivin, the Matterhorn of Greenland.

The next large incision after Angmagssalik Fiord is Sermiligâq, which in its outer part towards the west is bounded by a fairly large nameless island, and towards the east by several islands, among which are Erik the Red Island and Leif Island. The inner part of the fiord divides, like Sermilik, into two branches, in which broad glaciers come down to the sea between

large pointed mountains. The glaciers originate in local névés and not in the inland ice, which in this place is situated far away from the coast. Generally speaking, there are several glaciers among the many, partly snow-covered peaks, but there are no ice-covered areas of any large extent. In the sounds between the islands there are rapid currents, for which reason they rarely freeze over; therefore, Sermiligâq is an excellent sealing ground for the inhabitants of East Greenland.

The remaining part of the coast, as far as the northern boundary of the Angmagssalik District, has several considerable incisions, the most important of which is the 35 km long Kangerdlugssuatsiaq within Stor Island; the surrounding mountainous tract is impressively wild with tall, pointed naked peaks, which attain a height of 2300 m (Mt. Ingolf) only 5 km from the north side of the fiord. Farther inland there are still higher mountains.

North of Mt. Ingolf the inland ice comes down to the sea in a huge, 30 m broad glacier, Ikerssuaq, which by an "island" is divided into South and North Steenstrup Glacier, and is very productive.

Towards the north the outer land gradually decreases in breadth as far as Nûâlik. On an average the inland ice lies 20 km behind the coast. The coast line is broken up by several smaller fiords and bights (Poulsen Fiord, Kruuse Fiord) and islands, which occur in such great numbers at the Angmagssalik settlement, become very rare. In several places the glaciers come right down to the sea. In about lat. 67° N., there is an open ice-filled sea bay, Horror Bay, with a number of smaller islands outside it.

North of Nûâlik the inland ice takes possession; over long distances broad glaciers come right down to the sea, and only in a few places do naked peaks of 600—700 m altitude project as promontories, while numerous nunataqs rise above the inland ice. Facing the coast there are only a few inconsiderable islands, among which we may mention Agga Island and North Aputitêq. Finally, the whole of this area ends in the huge ice-fiord Kangerdlugssuaq (lat. 68° N.), which divides into three branches with glaciers at their heads.

THE NORTHERN CHRISTIAN IX LAND.

The Northern Christian IX Land extends from Kangerdlugssuaq (lat. 68° N.) to Scoresby Sound, including the south side of the fiord as far as Gaase Fiord (South Glacier) or, in other words, the whole of the triangular area where basalt is the predominant rock.

This region is indeed the least known along the east coast of Greenland, having only been visited throughout its whole extent by one scientific expedition—the Amdrup Expedition (1900). On the other hand, there are several accounts of vessels which have been beset by the ice and have been carried southward by it, but it must be taken for granted that inves-

tigations made in the course of such a passage will be more or less casual.

The central part of the Northern Christian IX Land is called Blosseville Coast after Blosseville, a lieutenant in the French Navy, who in 1833 from the man-of-war brig "La Lilloise" made a map sketch of this coast and sent it to France via Iceland. In the continued attempt at mapping the east coast of Greenland "La Lilloise" was presumably beset by the ice, and the whole of the crew perished.

The entire area, as mentioned, consists of basalt in almost horizontal banks, 20 to 30 m in thickness and interchanging with thin layers of tuff. Each basalt layer undoubtedly originates from one eruption and thus constitutes a lava stream. In a few places there are also minor layers of sedimentary rocks, slate and sandstone, which, like the basalt, dates from the Tertiary period. The greatest thickness is attained by the sediments at Cape Dalton.

By far the greater part of the peninsula which constitutes the northern part of King Christian IX Land is covered by inland ice, which in the central part of the coast, towards the Greenland Sea and at Scoresby Sound, almost comes down to the coast and forms productive glaciers, while there is a rather broad outer land towards south and north.

The coast itself is characterized by an interchange of steep promontories and fiords, the interiors of which are frequently reached by the inland ice. The basalt mountains form dentate, jagged crests.

"We have here," says Nordenskjöld, "the largest and most uniform basalt area in Greenland—the area can be calculated at more than 40,000 km, or somewhat less than half of Iceland—, and it therefore offers a good opportunity for the study of the topographic phenomena of a glaciated region of comparatively recent and uniform rocks," the few sedimentary layers found not affecting the topography to any considerable extent.

"Characteristic of the basalt area, in contrast with the area of Archaean rock, is in the first place the absence of fiords of any length, and then the wall-like, even if somewhat echinate boundary of the mountains, without any large pointed masses rising above the mean level. In this respect it recalls the sedimentary areas, though these by reason of the variation of the rock, show far greater irregularities and variation in detail." (Nordenskjöld).

Lowest and least incised is the coast in its southern part, from Kangerdlugssuaq to Cape I. A. D. Jensen, the promontory Nunap isua, however, being 900 m high. Here the ice-free outer land is also rather broad with a few local névés. From Cape Nansen the incisions become more numerous, and the coast line is split up into a number of promontories (Cape Garde *et al*), divided by fiords ending in glaciers, as the inland ice throughout this

part of the coast comes almost right down to the coast. The farther north, the higher the mountains, the highest point being Mt. Rigny which only 30 km from the coast attains a height of 2385 m. North of this the inland ice again recedes somewhat, so that the ice-free land becomes broader. It is thought that the inland ice again makes an advance against the sea, only slightly south of Cape Brewster.

Along the intermediary stretch, which attains heights of 1300 to 1600

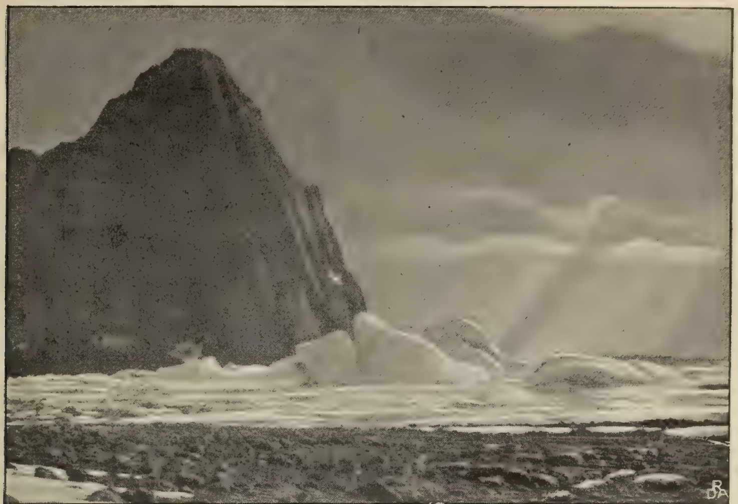

Fig. 13. Cape Garde (Northern Christian IX Land). (G. Amdrup).
A great part of the coast line of the Northern Christian IX Land is split up into a number of promontories with huge steep walls.

m, there are several local névés. Off the coast lies the 1045 m high Turner Island.

The extreme peninsula of Cape Brewster at the entrance to Scoresby Sound is comparatively low (330 m) and plateau-shaped, with steep walls towards the sea, and it is, further, divided by a lower region from the remaining country, for which reason the peninsula, when viewed from the north side of Scoresby Sound at Cape Stewart, gives the impression of being an island.

The north side of King Christian IX Land is "very uniform, without indentations or islands. The mountains form a fairly connected wall, with very few deep valleys and those filled with ice. The shape of the mountains is the one characteristic of basalt rocks, i. e. with pyramid-shaped peaks and fine stratification, especially prominent where snow covers the otherwise scarcely noticeable terraces. The peaks are often extended into ridges, but extensive plateaux rarely occur here on the coast border. The valleys that divide the ridges are certainly not typical corries, but are evidently due to ice erosion." Of very common occurrence are cirques. On a small

scale we find, as often in basalt mountains, a very sharp splitting up into small summits and pinnacles.

"Of particular interest within this basalt area are the valleys. In the same kind of rock and under the same natural conditions one cannot see a finer variety. Of least interest are the large valleys ending in glaciers which end up a number of fiords and evidently owe their origin to the combined effect of ice and water. Otherwise the fiords end up in true cirque walls where the rock bed, as it was exposed after the retirement of the eroding glacier, is visible everywhere, while a river flowing through in some canyon-like crevice tries to form a lower valley level.

"A splendid opportunity of studying these types of valleys occurs in the interior of Turner Sound between Turner Island and the mainland. Between the very steep, slightly defined, but typically V-shaped river chasms, and the long, often magnificent cirques with their sheer sides and gentle slope outwards, there is a vast difference, and yet the former probably only represent an early stage in the development that results in the latter, and the transition is marked by the insignificant "niche" depressions which at the top so often end up the valleys of the former class, where snow and ice have begun their work of first forming a corrie with its semicircular steep border, and then incessantly depressing and elongating the same.

"Especially on Turner Island, on the E. side of the sound, there are some very fine examples of such cirques which, divided only by narrow walls, run out at right angles to the sound from E. to W. In all these the bottom at the entrance lies at nearly the same height, about 200 m and in front of this level there is a slope towards the sea, which only forms a continuation of the normal fiord wall. Possibly the sea stood at about this level, when the main formation of the cirques took place. Through this slope the river from the cirque has cut its way down in a deep chasm, and in front of the valley we find a tendency to turn off from the S. E. direction towards the S. Supervening side valleys, also cirque-shaped, only occur subordinately. The length of the valleys seems to vary between 3 and 8 km and the breadth about 1 km" (Nordenskjöld).

Nordenskjöld gives a somewhat more detailed description of one of these valleys: "The river gorge, which at the mouth must have had a depth of about 50 m, becomes shallower and shallower at the top, and finally the river runs over a couple of not insignificant falls, but the rise is comparatively little until one reaches the inner ice-mass and its terminal moraine, the foot of which lies about 100 m and the upper surface about 200 m above the level of the valley bottom at the opening of the valley. The walls of the valleys are very steep, even if not always quite unsurmountable and have the "parabolic" shape characteristic of these valleys; there is no difference, in this respect, between the side walls and the front wall. The ice-mass, which is now inconsiderable in proportion to the extent of the valley, was

probably once the cause of its formation. Against the front wall itself lie some very steep masses of snow, probably consisting of ice in the interior. To these is attached, at the bottom of the valley, a mass of ice which was now covered by snow that—even in summer—was quite clean and free from gravel, while on the other hand the ice itself, when it appeared, was covered with masses of foreign substance. It is interspersed with fissures in two directions, partly narrow, sharp ones, partly hooklike ones corresponding most closely to structure bands."

Nordenskjöld further states that he "climbed the front wall in a little

Fig. 14. Jensen Fiord (Northern Christian IX Land). (G. Amdrup). Local glacier on the east side of the entrance to Jensen Fiord.

river cleft and found there that only a narrow crest, very steep and as sharp as a knife, separated the valley here described from another of a similar type, running in the opposite direction. This crest must necessarily break down gradually and then give rise to an "eid." The whole of Turner Island seems in this way to be divided up into smaller corries separated by narrow ridges. It is interesting to note that nothing similar occurs on the corresponding mainland where the mountains are far more closely joined and plateau-shaped.

"Since corries of such typical development rarely occur in a rock with such an evident alternation of strata," Nordenskjöld "took particular trouble to follow some characteristic basalt banks round the front wall in order to see whether any faults had contributed to the formation of the valley. It turned out that really a few small irregularities occurred, pointing to some minor dislocations such as are common everywhere in these basalts. But it seems to be equally certain that no large faults occur here, and while

the first foundation of the valley, as usual, must have stood in connection with the weakness of the rock along a dislocation line, the possibility of the whole actual valley originating in connection with a depression or a large fault seems to be entirely excluded."

SCORESBY SOUND ARCHIPELAGO.

Whereas Scoresby Sound, at the entrance between Cape Brewster and Cape Tobin, is only 28 km broad, it widens west of Jameson Land, both

Fig. 15. View from Hekla Harbour on Danmark Island in Scoresby Sund. (C. Ryder). In the background the characteristic basalt landforms of King Christian IX Land.

towards the south and north to a breadth of almost 200 km, at the same time, with its ramifications, cutting 300 km into the country. Thus Scoresby Sound becomes the greatest fiord system, not only of Greenland but of the world, besides being the place where the sea penetrates farthest into the huge island.

The whole of the inner part west of Hall Inlet is filled with islands and projecting peninsulas, so that the fiord branches into a large number of sounds and smaller fiords.

The greatest of the peninsulas is Gaase Land, bounded towards the south by Gaase Fiord which separates it from King Christian IX Land, and towards the north by Föhn Fiord and Vest Fiord, the interior part of which is situated at a distance of 300 km from Cape Brewster. North of Föhn Fiord lies the large island, Milne Land, which is otherwise washed by Røde Fiord, Sne Sound, Ö Fiord and Hall Inlet. The interior of the island is covered by a huge névé with many glaciers, hanging like festoons down the sides of the mountains. At the south side of Milne Land, off Föhn

Fiord and separated from the latter by Ren Sound, lies the smaller Danmark Island, where Ryder spent the winter 1891—92 in Hekla Harbour, from where he investigated and mapped the whole of the fiord system. At the north-eastern end of Milne Land lie a group of small islands, Bjørne Islands, and at the west coast Stor Island, Sorte Island and Røde Island. The next fairly large island is Ren Land, which is surrounded by Rype Fiord, Ö Fiord and Nordvest Fiord, the most northerly ramification of Scoresby Sound. Also this island is covered by a névé, sending numerous glaciers down towards the surrounding fiords, but only a few of these reach

Fig. 16. Ren Land in Scoreby Sound. (Chr. Kruuse).
The island Ren Land at the entrance to Nordvest Fiord filled with icebergs, seen from Jameson Land.

the sea. Towards the west Ren Land, through glacier ice, partly communicates with the inland ice, which in several places west of the islands comes down into the fiords, cutting into the country and forming more or less productive glaciers. Scoresby Land, north of Nordvest Fiord, is also covered with ice—a lobe from the inland ice shooting out far towards the east.

The Scoresby Sound Archepelago consists almost exclusively of different varieties of gneiss, which in the southern part—the north side of King Christian IX Land, Gaase Land and the south side of Milne Land—is superimposed by basalt to a height of up to 1000—about 2000 m. At Røde Fiord there are, in several places, occurrences of a very coarse red conglomerate, and on the south-easterly side of Milne Land a coarse-grained red or grey sandstone, the latter perhaps Jurrassic. Certain areas are covered by moraine with erratic boulders. On the naked rock surface there are very often distinct scratches (striæ), which show that the glaciers at one time must have taken up more space than they do now. The many glaciers cause fiords and sounds to be partly filled with icebergs and calved ice which, in addition to the

winter ice, greatly impede progress in these parts. Icebergs occur in great quantities, and several of these attain huge dimensions.

The coasts are in most localities steep and inaccessible. The greater part of the country consists of uplands, and the heights of the mountains increase the farther one penetrates into the fiords. In several places they attain heights of more than 2000 m, indeed, the nunataqs west of the fiords have been measured at 2200 m. Glorious alpine scenery occurs both on the mainland and on the island, but it is not nearly of such frequent occurrence as in the coast regions. The most widely distributed land-form is the split-up plateau or the roches moutonnées. Most plateau-like is, naturally, the southern part where the gneiss is superimposed by the basalt, but also Ren Land and the northern part of Milne Land, where the rock exclusively consists of gneiss, have a pronounced plateau shape and must presumably be regarded as a raised peneplane. Quite peculiar landscapes occur round Røde Fiord, where the prevailing kind of rock is the vivid red conglomerate, the gravel and stone layers of which are almost perpendicular. The smaller islands are comparatively low, the greatly incised Danmark Island, for instance, only attaining a height of 300 m. Røde Island is hardly more than 125 m in height. Bjørne Islands are, on an average, 100 to 200 m high, but above this altitude rise some sharp crests and peaks of up to 450 m in height. As the rock here consists of very weathered gneiss, there is nothing to prevent the alpine, peaked forms having been formed after the ice has receded. Lowlands also occur on the larger island off the coasts, for instance on the south-eastern side of Milne Land east of Mudder Bay where the rock is sandstone.

JAMESON LAND.

Towards the east Jameson Land is bounded by Carlsberg Fiord, Klitdal and Hurry Inlet, towards the south and west by Scoresby Sound and Hall Inlet, terminating in Nordost Bay, and towards the north by Scoresby Land.

Jameson Land is one of the most characteristic areas in all East Greenland. William Scoresby junior describes the southern parts of the country, espicially the environs of Cape Stewart as being on a par with England as regards the rich developments of vegetation, and all travellers must agree with Scoresby that Jameson Land is a most peculiar Polar country. When arriving here in summer one sees a grass carpet so fresh that it is not to be equalled in many other places of the globe, and among the grass grow numerous flowering plants: *Ranunculus*, cornflower, yellow *Papaver*, *Cassiope*, *Saxifraga*, *Cerastium*, *Silene*, *Taraxacum*, *Dryas octopetala* and many others, besides creeping willow (*Salix polaris*) and birch (*Betula nana*). Among the flowers butterflies flutter together with bees and myriads of other insects,

while mosquitos at times make a stay in those parts almost unbearable. It is hardly to be realized that one is in lat. 70° N.

Jameson Land—in particular the southerly part—is comparatively low, level, and in summer practically free from ice. The ground seems to consist entirely of sandstone belonging to the Triassic-Jurassic period, almost horizontal or slightly inclining towards the west. The Jurassic formations are exposed, for instance, at Cape Stewart and the regions north of that at Hurry Inlet as well as in a single place on the west coast at Aucella River.

Fig. 17. Jameson Land (Einar Storgaard).
In the plateau land a river has eroded a deep V-shaped valley. In the background the northern coast of King Christian IX Land across Scoresby Sound (about 40 km).

Otherwise it is covered by Quartenary formations, particularly of marine or fluvioglacial origin, in a lesser degree consisting of moraine material.

Jameson Land is most elevated towards the north, where certain peaks attain a height of 1000 m or more; towards Hurry Inlet the country is bounded by a steep wall, up to 600 m in height, while towards the west and south it slopes gradually to the surface of the sea. Therefore, it is natural to divide the country into a northeasterly highland and a southwesterly lowland.

The northerly highland, according to Nordenskjöld, "consists mainly of isolated rocky, mountainous hills, separated by deep valleys with rather steep sides, though not by real canyons. These mountains are also sometimes covered with ice. But already a little farther south these elevations close up, so that one can speak of a true plateau which slowly rises from Ryder's

Dale from 150 to about 900 m, and is only interrupted here and there by shallow river valleys. The plateau is covered by a large, level, connected cap—usually of some metres in depth—of coarse, very well-rounded and washed-out gravel, consisting of the greatest variety of rocks: granite, syenite, pegmatite, quartzite, etc., but not basalt. The variation of blocks shows that they undoubtedly derive from the W. Large blocks of more than about 2 m in height are exceedingly rare. Up here the gravel is evenly distributed; farther south, however, one can often observe an arrangement according to the type of shore gravel; here are also huge layers of fine sand, which are lacking in the upper plateau; sometimes there even occur extensive fields of blocks of well-rounded stones, mostly covering lower districts; and, finally, there are "osar" or estuary terraces of glacial rivers, 4—5 m in height and 10—30 m in length and formed of small well-washed pebbles. The same well-rounded gravel, though in less quantity, occurs up on the plateau heights right down to Cape Stewart."

This "gravel" is deposited by large glacier-rivers, although Nordenskjöld hesitates to deny that much is in favour of its being of marine origin; on the other hand, he refuses to believe that such an enormous rise (1000 m) has taken place since the glacial period, but supposes that there may have been a large inland sea basin.

At Cape Stewart, where I have had an opportunity of making personal investigations, I have no doubt whatsoever that the surface is a raised sea-bottom from the time directly after the glacial period.

The surface of the plateau is here, over large areas, quite level, only now and then broken by faintly vaulted hills, which in the "sea period" must have projected like islands, undoubtedly with steeper bluffs than at the present time. The rounded forms which they now present are the result of the solifluction, in that the melting water which forms in spring and summer cannot sink into the ground, for which reason the upper layers get soft and slide down—in other words, the same process which in the tundra period has given Denmark its even, soft forms. The rise has evidently taken place in three stages, as towards Hurry Inlet there are terraces below the plateau, the former now containing the western dwelling place of the Scoresby Sound settlement, whereas the other, the low sandy shore, gradually sinks below the surface of the sea.

In the very surface of the plateau, the rivers, after the rise, have eroded deep valleys, which are distinguished by their typical V-shape, as appears from fig. 17.

The stones on the plateau as well as the fossiliferous Jurrassic boulders in the valleys, bear traces of the agency of the frost. Along the sides of the valley they lie more or less loosely; frequently only very little movement is required to make them topple over, and they then rush down into the river bed, trailing gravel and smaller stones after them, for which reason

people ascending such steep valley sides should be careful not to follow directly in the tracks of each other.

Along Hurry Inlet the Jurrassic beds usually form "a steep, often insurmountable rocky wall, at the foot of which are terraces and often extensive moraine-like formations. It is most probable that here under the lee of the high perpendicular wall, huge abruptly dipping drifts of snow and ice have lodged for certain periods of time. Under the influence of wind and thaw-water, gravel and dust have been carried out into their surface and then, when the snow melted, collected at the foot where they still lie like embankments." (Nordenskjöld).

The eastern slope itself is furrowed by numerous V-shaped erosion val-

Fig. 18. Neills Cliffs (Ch. Kruuse).
The eastern slope of Jameson Land, furrowed by numerous V-shaped erosion valleys.

leys, in which, even in summer, snow drifts can be met with. "Nearest the shore there is a number of very short and deep, steep chasms which, as one gets higher up to the verge of the plateau itself, widen out and are continued in gentle, not conspicuous depressions.

"The larger valleys belong to the same type, and in their lower part form wild, often impassable chasms. Up country they suddenly come to an end, like a sack, against a steep wall which is often roofed by a mass of ice, usually in an almost dead condition. These are the only occurrences of glaciers to be found in these parts. And should there be any continuation at all of the valley further inland it only forms a shallow flat depression in the plateau, usually filled with snow; nothing analogous to the canyon-like chasm-valleys of the coastal area is to be found in the interior of the country." (Nordenskjöld). This is explained by the fact than "on a lower level rivers of thaw-water have a very erosive effect in the summer, whereas higher up, where the snow does not melt, but only

evaporates, almost every erosive activity somewhat suddenly ceases." (Nordenskjöld).

In the south-western lowland there is only in a few deep valleys towards the south a foundation of solid sandstone rock. Here on the coast, in the neighbourhood of Cape Hooker, this sandstone is superimposed by clay with numerous stones, a formation which undoubtedly derives from a sea where, at the same time, blocks of ice had drifted about. Above the clay one usually finds moderately fine sand, and above this a cover of coarse gravel, similar to that just described in the case of the mountain plateau. Farther towards the north-west the soil is formed of sand and fine gravel. Along the coast formations of dune sand are extensive.

"Outside the coast-line lies a broad plateau which is so shallow and shelving that a landing is only possible at high water" (Nordenskjöld), and the same holds good in the case of the dwelling place at Cape Stewart. "At the shore itself there is a 5° to 15° declination consisting of sand. Within this embankment there is now and again a depression, or else a terrace plateau begins at once, rising very slowly scarcely 100 m in 5 to 10 km. This terrace is cut up nearest the coast by innumerable short, deep, sheer river valleys. Several of the valleys are only a few hundred metres in length; others are widely forked and reach far inland; but all show a strong tendency to come to an abrupt termination against a steep wall, which is probably formed in that the brooks rise from springs which have gradually succeeded in carrying away the masses of earth lying before and over them.

"Very few water courses reach the interior of Jameson Land, and their valleys are broad and not especially marked" (Nordenskjöld).

Before leaving Jameson Land we must attempt to explain the peculiar fact that this plateau-land of up to 1000 m high is in summer practically free from snow and ice. It cannot be owing to purely climatic causes: the inland ice in Scoresby Sound seems to come close to the northern boundary of Jameson Land, and to the east the interior of Liverpool Land is filled with extensive névés. An attempt has then been made to explain it by topographical and pedological conditions. "Very probably the plateau character has been unfavourable to the formation of ice, both because it discourages atmospheric precipitation and because the snow that falls here is easily carried away by the wind; but it is also possible that the precipitation at the level that the plateau reaches here within the fiord is less than out by the coast." (Nordenskjöld).

As a further cause of the freedom from ice Otto Nordenskjöld mentions the porosity of the rocks, as the melting water is apt to sink into the loose soil, which hinders the formation of a crust of ice on the ground, or in some other way prevents the snow turning into ice.

According to Nordenskjöld the same conditions perhaps prevailed within the ice age, for Jameson Land does not seem to have been covered with

ice during this epoch, as typical moraine formations have not been found anywhere.

LIVERPOOL LAND.

As something quite foreign to the sedimentary plateau the peninsula Liverpool Land extends from Jameson Land and still farther towards the east. Liverpool Land consists of gneiss and is a horst, bounded on the north by Carlsberg Fiord, on the east by the Greenland Sea, on the south by Scoresby Sound and on the west by Hurry Inlet and the depression continuing in the same direction towards Carlsberg Fiord, in part traversed by Ryder River.

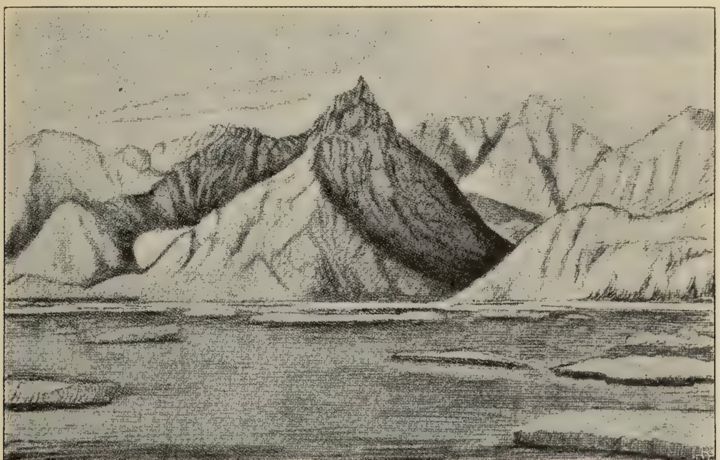

Fig. 19. Liverpool Coast near Cape Grey (E. Ditlevsen)
The eastern side of Liverpool Land is a wildly jagged alpine landscape. The rocks consist of gneiss.

Within recent years, Liverpool Land has attained added importance, in that three of the four dwelling places of the new Scoresby Sound settlement have been founded along its southern side, for which reason this part of the country will be described in greater detail, the description being chiefly based upon the statements of Nathorst and Nordenskjöld, as well as upon scattered personal observations.

Viewed from the sea the east side of Liverpool Land—the Liverpool Coast proper—appears like a wildly jagged, alpine landscape "and in this respect it is hardly excelled by any other stretch of the coast in the surroundings of Scoresby Sound, and that despite the fact that the mountains do not exceed 1000—1200 m in height" (Nordenskjöld)—the highest point being estimated at 1255 m. "The dip to the sea is usually very steep, often impossible to climb, but not very high. At about right angles to the coast line a number of valleys intrude, rather short but comparatively very deep and broad and often filled with huge glaciers" (Nordenskjöld). Islands

outside the coast only occur in small numbers, but several of those present bold, sharply pointed mountain-forms such as Rathbone Island and Murray Island. "The highest peaks lie somewhat inland, but only at a short distance from the shore, and rise in strange wildness often almost perpendicularly, as for instance the Church Mountain and Tvillingerne, separated from each other by deep corries and giddy bold ridges. The ice-covering is very extensive, but not prevalent, even inland." (Nordenskjöld). Judging by the alpine forms the mountains here have projected like nunataqs, even when during the glacial period the inland ice extended all the way down to the sea.

Quite different is the appearance presented by the land when viewed from the south. Here the whole country is lower, and at the same time all the hills are rounded—in several of them there are extremely beautiful cirques (Fig. 20). The soil consists of greatly split and weathered gneiss. Viewed from the sea the land presents a perfectly desolate appearance, but although the naked soil predominates, there are, nevertheless, a great number of plants among the rocks. At Cape Hope where one of the dwelling places is situated there is, however, a flat stretch, a couple of kilometres long and half a kilometre broad and almost exclusively covered by fresh-green grass or, in the more humid places, by moss. The soil here consists of sandstone, divided from the gneiss area by a fault line immediately to the west of the houses. To the east of these there is in the coast cliff a thin layer of coal, of a similar appearence as the Rhaetic coals at Cape Stewart.

The south coast itself is greatly cut up by rounded bays, in which respect it differs both from the east coast and the west coast. The largest incision is Rosenvinge Bay, the interior of which is Hvalros Bay. Here—at Ferslev Point—lies the main station of the Scoresby Sound settlement with an excellent 3 km long, ½ km broad harbour—Amdrup Harbour.

"The land rises slowly from the shore with a shallow inclination. The mountains in the east are quite high and wild with deep valleys of all types that are usual in such mountainous districts. Towards the west this mountainous landscape passes over gradually into the level, plateau-like foreland which from a considerable height slowly sinks towards the West. The slope to the south is fairly steep, the valleys short, steep and deep, ending in comparatively gentle deep chasms. Down against the lowland at the coast extend ridges with gentle, rounded crests; between these must lie—or must have lain—glaciers. Farthest to the S. E. the land gets lower, flat and covered by a huge dome-like mass of ice. The low foreland at the extreme headlands is fairly free of snow in summer" (Nordenskjöld).

The western slope of Liverpool Land, according to Nordenskjöld, falls into "three different longitudinal zones, *viz.* the nunataqs, the foreland and the shore-land. The nunataqs are situated farthest in, steep and often very pointed, surrounded by masses of ice and presumably all situated rather far E. and mostly identical with the peaks already spoken of as visible from the

E. coast. A long sloping foreland is beginning at a height of about 600 m; it is quite devoid of all peaks and from a distance gives the impression of a plateau, while in detail the slopes appear with the rounded forms of "roches moutonnées" with typical lee side to the W. and partly covered with débris, formed by disintegration of the rock in place, partly with true, somewhat washed-out moraine débris, whose connection with the ice-masses soon to be met with within the E. is apparent. The "hillocks" themselves, obtain a height of 50 m or more above the level of the plateau.

"The foreland passes gradually to the W. into the true shoreland, a zone of a breadth of up to a few km where solid rock either does not appear

Fig. 20. Hvalros Bay on the south side of Liverpool Land (Einar Storgaard). In the mountain a characteristic cirque. The central station of the new Scoresby Sound Settlement lies just to the right of the picture.

at all or only in deeper cuttings, while for the rest the ground is chiefly composed of rounded gravel and sand. The latter sometimes forms perpendicular walls facing the sea, rising to 25 m in height.

"Beginning on the precipice we come across an even gravel terrace, 20—40 m above the sea. Above this terrace there rise in many places, especially as one proceeds inland, numerous more or less irregular, often steep ridges or banks, rising to a height of 30—40 m or more above the surroundings. These long banks which occur especially at the N. E. corner of Hurry Inlet, often misleadingly recall moraines; however, they consist of gravel composed of local rocks, and large blocks are lacking. They are presumably a kind of river terraces; at the same time it must be observed that real moraine ridges seem to occur under similar conditions, especially farther south.

"Harbours and bays are lacking on this coast and that depends exclusively on the presence of this area of deposition the reverse of the usual denudation areas on such coasts. For the highland itself is interspersed with transverse valleys, whose U-form is unmistakable, and which are clearly distinguished from the usual steeply sloping valleys of river erosion, which latter are numerous here also." (Nordenskjöld).

The whole of the interior of Liverpool Land seems to be covered by névés, from which numerous glaciers proceed. In the southern part none of these reach the sea or the fiord, while on the other hand there are several which debouch into the Carlsberg Fiord towards the north.

On the south coast of Liverpool Land—near Cape Tobin and Cape Hope—are several warm springs.

KING OSCAR ARCHIPELAGO.

The German Expedition, under the command of Koldewey and Payer (1869—70), and the Swedish Expedition, under the command of A. G. Nathorst (1899), discovered and mapped an area which in several respects is one of the most interesting along the whole of the east coast of Greenland. It consists of a great number of islands and peninsulas between Carlsberg Fiord in the south and Mackenzie Bay on Hudson Land in the north. The islands and peninsulas are separated from each other by greatly ramified sounds and fiords.

The whole of this welter of islands and peninsulas, which form a naturally defined geographical area, has hitherto been nameless. As it is more particularly through the efforts of the Swedish Expedition that we have obtained our knowledge, at any rate of the interior parts of this fiord system, I propose that in the future it should be called *King Oscar Archipelago*.

The most southerly of the deep incisions is Davy Sound, the interior part of which was named King Oscar Fiord by Nathorst when the Swedish Expedition arrived in it from the north. From a glance at the map it will appear that King Oscar Fiord is a direct continuation of Davy Sound, and there is no geographical reason whatsoever for changing the name of the fiord at the imaginary line between Dröm Bay and Traill Island and Mästers Vik on the north side of Scoresby Land, especially as Scoresby, in his map of Greenland (1822), indicates the outline of the coast on the other side of Mt. Pictet and Werner Mountains and, further, in his "Journal of a Voyage—1822" writes that "between Cape Pictet and Traill Island Davy's Sound runs towards the north-west to an extent that, being beyond the reach of vision, could not be determined." The name King Oscar Fiord should therefore be restricted to the north-going branch of Davy Sound, corresponding to Segelsällskapet Fiord.

From Davy Sound other fiords cut deeply into the mainland; at its mouth Nathorst Fiord and Flemming Inlet, farther in Segelsällskapet

Fig. 21. Hanging glacier, Davy Sound (Chr. Kruuse).
The hanging glacier comes down from the highland ice on the southern side of Forsblad Fiord. Height of the wall about 1500 m.

Fiord terminating in two branches, Alpe Fiord and Forsblad Fiord. North of the latter the peninsula Lyell Land extends far towards the east. In the north it is bounded by Kempe Fiord, which is divided into three branches, Rhedin Fiord, Rohss Fiord and Dickson Fiord. Rhedin Fiord is so close

to Forsblad Fiord that Lyell Land communicates with the mainland only by a narrow, but high isthmus. The same applies to the next large peninsula, Suess Land, which towards the north is washed by Antarctic Sound and the inner part of Franz Joseph Fiord, which terminates in two branches. North of Franz Joseph Fiord lie four large peninsulas, Frænkel Peninsula, Andrée Land, Strindberg Peninsula and Gauss Peninsula, separated from each other by the Is Fiord, Geolog Fiord and Nord Fiord. The latter peninsula extends towards the west from Hudson Land, from which it is separated by Moskusokse Fiord.

The three largest islands are Traill Island, north and east of Davy Sound, Geographical Society Island which to the south is washed by Vega Sound, to the north by Sophia Sound, and Ymer Island, surrounded by Sophia Sound and Antarctic Sound to the south and Franz Joseph Fiord to the north; in the eastern part of this island Dusén Fiord cuts far inland. Of the smaller islands special mention should be made of Ruth Island, Maria Island and Ella Island in the northern part of Davy Sound, Hammar Island, Åkerblom Island, Jägmäster Island, Arvedsson Island at the mouth of and within Segelsälskapets Fiord and Archer Islands farthest out in Davy Sound. In Vega Sound lie Scott Keltie Islands, at the east end of Ymer Island, including Wijkander Island and Brock Islands and, in Mountnorris Inlet, which from the east cuts into Traill Island, Craig Islands. Out in the sea lie Bontekoe Island, separated from the mainland by Foster Bay, Mackenzie Island and Franklin Island.

What makes this area particularly interesting are the geological conditions. Nearest the inland ice the land consists of gneiss and other Archean rocks, but outside these, in the northern part of Scoresby Land, the eastern parts of Lyell Land, Suess Land, Andrée Land, the greater part of Strindberg Peninsula, the western part of Ymer Island as well as the islands in Davy Sound, follows a belt of Cambrian-Silurian strata, consisting of variegated limestones, dolomite, slate, and red and yellow sandstone, which are folded and greatly pressed, while the succeeding belt chiefly consists of almost horizontal, or at any rate only slightly folded layers of red and grey Devonian sandstone. The eastern parts are still little known from a geological point of view. Basalt occurs on Traill Island, Geographical Society Island, Gauss Peninsula and Bontekoe Island. Finally, there are on the most easterly projection of Traill Island palæozoic eruptive rocks.

South of the mouth of Davy Sound, from Carlsberg Fiord and up to some distance past Antarctic Harbour, there are partly conglomerates, limestone, sandstone, etc. of unknown age and partly sandstone, slate and limestone from the Triassic and, perhaps, the Jurassic period.

The peninsula, Canning Land, west of Carlsberg Fiord, according to Nordenskjöld "consists of a number of narrow isolated ridges and caves,

not of true peaks divided by deep and very typical corries, and also by ordinary crevices. The slope towards the sea is very steep, and in detail all the heights are sharply moulded out in peaks and ridges. This topography is connected with the rich variety of rocks—sandstone, slate, limestone—in the formation of which huge, almost massive banks of calcareous sandstone enter, as do also not inconsiderable quantities of the surface eruptives. The beds dip rather abruptly, and the emanating strata tops of harder beds produce peaked points projecting from the ridges.

"In Flemming Inlet there is a series of gentle mountains, rising in terrace-like plateaux, according to the various banks of rock; through the often

Fig. 22. Syltoppene in Scoresby Land on the south side of Davy Sound (Åkerblom and Nathorst).
The sharp peaks of Syltoppene are probabley due to the resistance to erosion in certain hard banks of the folded sedementary rocks. Height 1570 m.

considerable thickness of these banks the type is well distinguished from the basalt rocks. The peaks that rise above the mean level, are, as a rule, flat pyramid shaped. The valleys here are not entirely fiord-like, not even the very considerable Örsted Valley. They are certainly often eroded deep down, but are short and broad, probably emptied glacier valleys with lateral valleys which end somewhat abruptly, but so that the innermost gorges are more angular and relatively more broad at the top than usual in corries. If there were really corries here once, their shape has been partly destroyed. The numerous minor valleys are wild and deep, with sheer slopes and end in narrow clefts, of the true mountain-river type. A dissimilarity to the fiords in harder rocks arises in territories such as these already by reason of the sides of the valleys not being rounded off, but being either more gently sloping, or, owing to breaking up through erosion and abrasion,

angular or even precipitous, which is easily explained by the nature of the rock itself. A very narrow foreland outside the coast steep is usually present, before every river it widens considerably owing to masses of gravel carried down.—On the N. W. the fiord is bounded by an almost plateau-shaped wall, the isolated peaks everywhere showing the strong tendency to assume pyramidal shape.

"The south coast of Davy Sound is soft and low, without prominent peaks, but sometimes broken up into crest-shaped hills". Farther inland the land becomes higher—Mt. Pictet is 1700 m, and still farther in, at the most southerly ramification of Davy Sound, we find "very high mountains (2000 m). Where the mountains consist of horizontal sedimentary beds, they have most often a tendency to a plateau shape. The wildest mountains are the so-called Syltoppene whose sharp characteristic peaks are probably due to the resistance to erosion in certain hard banks of the folded sedimentary rocks (fig. 22). Traill Island consists of isolated rounded masses, divided by steep valleys and themselves cut up by numerous small valleys and chasms. Real peaks are generally lacking, except perhaps farthest out to Cape Simpson" (Nordenskjöld). The island is highest towards the northwest, where it attains a height of 1580 m. Geographical Society Island and Ymer Island also reach heights of 1400 to 1500 m near the coast, their interiors being covered by ice and snow.

But steepest are the walls in the fiords within the innermost ramifications. To heights of 1200—1800 m they rise, almost perpendicularly, above the surface of the sea, and the mountains are distinguished by red-yellow-grey colours. Numerous waterfalls rush down from hanging valleys into the fiords, full of icebergs originating in the many glaciers which come down from the inland ice and the local névé areas.

On the peninsula Lyell Land special attention should be paid to Mt. Berselius, which with its almost horizontal stratification is distinctly plateau-shaped and attains a height of 1800 m a couple of kilometres from the coast. North of that the great Wahlenberg Glacier debouches. The west end of Ella Island is called Bastionen (1210 m), and it stands with quite perpendicular walls, while Ruth Island is rather conical in shape. Skildvagten on Suess Land is said to suggest Devil's Thumb in West Greenland, but in height it is inferior to Payer Spitze (2100 m) on the north side of the peninsula. In the interior of Franz Joseph Fiord the Nordenskjöld Glacier debouches, and behind it Mt. Petermann (Petermann Spitze) is visible, its summit attaining a height of about 2800 m.

The three peninsulas situated between Nordenskjöld Glacier and the huge Waltershausen Glacier, which debouches into Nord Fiord and is divided by Is Fiord and Geolog Fiord, are named after the members of the Andrée Expedition, Frænkel, Andrée and Strindberg. The surroundings of this, the inner part of Franz Joseph Fiord, are extremely grand and im-

pressive. In the very innermost part the heights on both sides are particularly great. On the peninsula between Nordenskjöld Glacier and Kjerulf Fiord towers, to a height of 1800 m, the peculiar square peak of Ridderborgen, and of Ätteslupen on the south side of Frænkel Peninsula, Nathorst says that it "rose so high and steep that it was necessary to bend the head far backwards when wanting to see the summit." On the midmost and greatest of the peninsulas—Andrée Land is situated in a place where the fiord contracts somewhat and where the passage, therefore, becomes more difficult—lies the glorious Teufelschloss. Of this area Payer writes: "We had got into a deep basin (Franz Joseph Fiord), which consisted of rocks, the like of

Fig. 23. Franz Joseph Fiord (Koldewey and Payer).
The huge rocky walls of Franz Joseph Fiord attain a height of 1800 m.

which, in glorious shapes and colours, I had never yet seen. The peculiarities of the alpine world, huge rocky walls, deep erosion chasms, wild mountain peaks, colossal broken glaciers, foaming rivulets and water falls, etc., of a grandeur which may occur in isolated cases in our part of the world, all of these pictures were here taken in at a single glance . . . From a small base a huge cube-shaped mountain block extended like an isthmus out into the fiord, this mass rising directly from out of the blue water to a height of 1500 m. Regular streaks of tawny, black and lighter colours show the stratification of the rocks. Tower-like peaks rising from its edges lend to it the appearance of a ruined castle. We called it Teufelschloss, and I do not remember anywhere in the Alps to have seen a view approaching it in splendour." Strindberg Peninsula is lower (1000 to 1100 m), but on Gauss Peninsula there are again peaks of 1400 to 1500 m.

In Franz Joseph Fiord the Swedish Expedition undertook a few bathymetrical measurings, the results obtained being 634 m south of Frænkel Peninsula, 763 m south of Andrée Land, but only 291 and 176 m south of Gauss Peninsula at the mouth of the fiord. In other words, the same conditions are found to prevail as in the Norwegian and other fiords, which partly owe their origin to the ice; the fiord is deeply excavated in its inner parts, whereas there is a sill at its mouth. However, there is also a possibility that other forces may have been at work towards the formation of the fiords and sounds, principally displacements in the earth's crust. The Silurian and Devonian formations are possibly divided from each other by a fault line, running parralle with the coast, but Nathorst is of the opinion that there are also smaller dislocations at right angles to the coast line. That foldings have taken place, is distinctly visible in the Silurian strata.

HUDSON LAND—KING WILHELM LAND.

From Mackenzie Bay in the south to Dove Bay in the north there are a number of peninsulas and islands which are still very little known. The whole of this area consists of Hudson Land and King Wilhelm Land with the islands lying in front of it, *viz.* Clavering Island, Sabine Island, Pendulum Island and Kuhn Island.

Hudson Land, whose two promontories, Cape Hold-with-Hope and Cape James, consist of basalt, are otherwise comparatively unknown, but Precambrian rock will undoubtedly prove to predominate. In the broad Gael Hamke Bay, north of Hudson Land, lies Clavering Island, the chief constituent of which is gneiss, whereas its most easterly promontory, Cape Mary, is covered with basalt.

The peninsula within Clavering Island (with the promontory Cape Blosseville) is also composed of gneiss, and the same holds good of the greater part of the long peninsula, which towards the east terminates in the 1140 m high Sadel Mountain. The east side, Cape Borlase Warren, on the other hand, consists of basalt with isolated occurrences of different sediments, and this also applies to Sabine Island and Pendulum Island, which are situated north-east of Sadelbjerg Peninsula.

"Pendulum Island forms a gently dipping, monotonous plateau (616 m), Sabine Island, too, is similarly rather monotonous, although the numerous interlocated beds of Tertiary sandstone in the basalt make its contours softer, and in any case it never assumes the appearance of a true plateau. There are various steep walls and ridges, both towards the sea and towards some rather deep valleys, which however are not typical cirques. On the other hand, pointed peaks are entirely lacking; the highest tops (685 m) only form gently rounded eminences which rise from the upper

Fig. 24. The northwestern point of Shannon Island (Ejnar Mikkelsen).

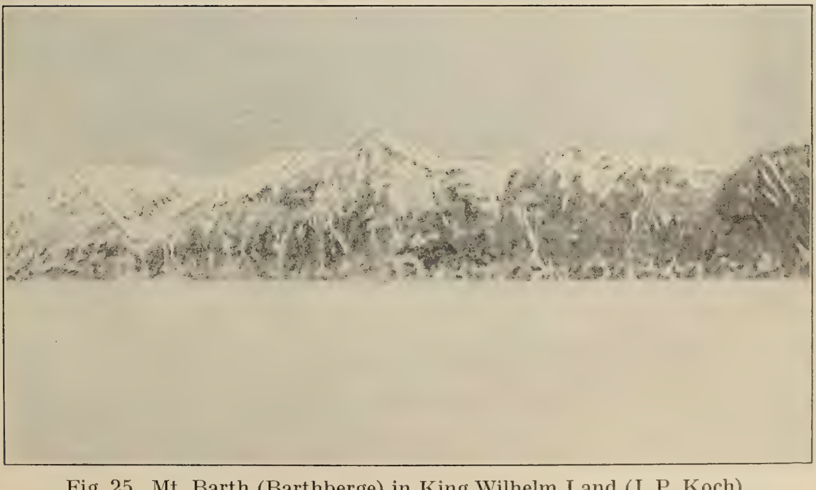

Fig. 25. Mt. Barth (Barthberge) in King Wilhelm Land (I. P. Koch).
Barthberge with Wildspitse (1600 m) shows a transition form between the plateau land and the alpine landscape. The mountains viewed from Ardencaple Inlet.

part of the mean level, which is always about the same height, whether it be situated in plateaux or ridges. The coast line is tolerably uniform, and Germania Harbour is only a rounded creek, surrounded by low steep walls, in a low, gravel covered basalt plateau, closely recalling a peneplain resulting from supramarine erosion" (Nordenskjöld).

Sediments also occur on Kuhn Island, which otherwise consists of Precambrian rock. On the mainland west of Kuhn Island the inland ice comes almost down to the sea, and a little farther north Ardencaple Inlet cuts far into the land, being finally divided into two arms, Smalle Fiord and Brede Fiord. The southern part of King Wilhelm Land is called Hochstetter Foreland, and it consists of almost horizontal yellow and red sandstone (Jurassic); the greater part of it is quite flat and low, and the highest point (towards the south) is 385 m. Also Shannon Island is rather low (305 m), and of a plateau-like character. The southern part of the island consists of basalt, the northern of gneiss. Shannon Island is the most northerly basalt occurrence. There can hardly be any doubt that the number of basalt occurrences, beginning north of Traill Island and then continuing in a straight line to Shannon Island, have sprung up along a fault line passing north to south.

The inner part of King Wilhelm Land which consists of gneiss, attains comparatively great heights (1667 m), but chiefly with plateau-like forms, Mt. Barth, however, being more alpine in character. Bessel Fiord divides the main part of King Wilhelm Land from a peninsula to the north of which —in Dove Bay—there is a fairly large number of rather low islands (up to 400 m).

GERMANIA LAND.

The peninsula Germania Land, between Dove Bay in the south and Jökel Bay in the north is, in the main, constructed of almost horizontal layers of gneiss. Only farthest towards the north are there sediments which are considered Tertiary. The islands Little Koldewey and Great Koldewey also consist of Archean rock, but on the east side of Great Koldewey sandstone from the Jurassic and the Cretaceous periods occurs. In the west Germania Land joins the huge glacier Storströmmen. Of the incisions the broad Skær Fiord is the most considerable. From this fiord issue, in their turn, several fiords, *inter alia* Penthiévre Fiord with C. Silverberg Island and Joinville Island. Germania Land is the most considerable ice-free area of north-eastern Greenland; only four rather small local névés being distributed over the great area.

"The western part of Germania Land between Helle Fiord and Cape Récamier forms," according to I. P. Koch, "a nearly horizontal plateau, the altitude of which above the level of the sea is 800 m. The declivity towards the east is rather steep; towards the west the plateau slopes gently

in the direction of the inland ice. The surface of the plateau is slightly undulating, the solid rock is in this place completely hidden by loose stones; clay does not occur at all; gravel and sand only appear sporadically in quite small quantities among the stones. The bulk of the loose stones are products of disintegration belonging to the place itself; still, also blocks of sandstone

Fig. 26. Danmark Monument in Germania Land (I. P. Koch).
In the western part of Germania Land the plateau land-forms prevail, intersected by deep clefts with up to 800 m in height. To the left Pustervig, to the right Mörke Fiord. The picture is seen from the east.

occur and of a sort of red granite, which is not indigenous and therefore suggests transport by the ice.

"Water courses do not occur up on the plateaux; on the other hand one may here and there come across a small lake.

"The plateaux of Germania Land are intersected by three deep clefts, very similar to crevasses with steep rocky walls; two of these clefts lodge Annekssöen (Anneks Lake) and Sælsöen (Sæl Lake), the third is partly filled up by Mörke Fiord (fig. 3). The considerable glacial activity which

has taken place through these depressions appears partly from the worn and rounded walls of rocks, of which in particular the north side of the Danmark Monument is a splendid example, partly also from the frequently occurring moraines. Considerable lateral moraines are thus to be found near the Danmark Monument, west and south of Rypefjeldet at the east point of Væderen (i. e. the ram) and along either side of Sælsöen. Terminal moraines occur at the western end of Sælsöen and in the eastern part of Annekssöen."

In other parts of Germania Land the moutonnéed land-form is the prevailing one. "The hills consist of more or less denuded bedrock, which is polished smooth by the ice to such an extent that its surface has become as even as flagged but undulating ground. Of the loose material which the ice left on the peaks, when it melted off, the fine grinding powder has been washed down into the hollows, and only a few scattered, larger or smaller, loose stones remain.—In the immediate neighbourhood of the coast the moutonnéed land-form may assume a materially different aspect. The belt of rocks and islands girding the coast east of Danmark Harbour is a case in point. In this place we do not meet with continuous ranges of hills, but with great quantities of detached, low, rounded hills with small irregular depressions in between. Here there is not sufficient material available for the levelling of the depressions; instead of that they are partly filled up with a large quantity of quite small lakes and ponds, the surface of which is often only a few metres above the level of the sea" (I. P. Koch).

The same moutonnéed land-form also occurs on the small islands and rocks in Dove Bay. The northern part of Germania Land between Skær Fiord and Jökel Bay, as well as the eastern parts, consists of transition forms between "the typical plateau landforms and the typical moutonnéed land-forms—of undulating mountain areas of 300 to 600 m altitude. They are grey and bleak stone deserts, the surface of which consists of loose stones and gravel, through which the worn and rounded rock projects here and there. Now and then one may come across a small lake or a narrow water course, but apart from that the only enlivening factors are the perennial snow drifts which, like white splashes, are strewn all over the grey land" (Koch). Also Moskusokse Mountains (578 m) which form a natural continuation of Great Koldewey, belongs to the transition forms.

Close to the margin of the inland ice, along the west side of Germania Land, there are moraine deposits on a large scale, and the same is the case at Hval Plain (Hvalsletten).

As Germania Land has a comparatively large breadth and, further, is not dissolved by deep-going fiords into too many peninsulas and islands, there is here room for lakes and rivers, of dimensions which are otherwise rarely met with in the greatly intersected outer land.

In the preceding we have already mentioned that "small lakes, ponds and rivulets occur in very great numbers in the moutonnéed rocks along

the coast. In an area west of Stormelven of about 16 km² there were about 30 little lakes and water holes and a very great number of rivulets. The result of the high-arctic climatic conditions is, however, that the small lakes and rivulets, so to speak, only exist for a short period of the year, in that an essential part of the fauna and vegetation of North-east Greenland is bound up with them.

"During the first half of June the melting of the snow begins; the melting water accumulates in the rivulets, which in June reach such a magnitude that many of them become troublesome obstacles in the path of the traveller.

Fig. 27. Hval Plain (Hvalsletten) and the eastern end of Sæl Lake (Sælsöen) (I. P.Koch).
Sæl Lake (Sælsöen) in Germania Land is one of the largest lakes in Greenland, being 50 km long.

During the first part of July the water courses attain their maximum; in the latter half of July they decrease to a very perceptible degree, and from the beginning of October all the little rivers cease to run. The beds of the rivers are often hidden under the winter snow. The water courses which every year must excavate and melt a bed for themselves in the snow, in this manner are often made to float in a deep channel which on either side is bounded by steep snow walls and spanned by more or less safe snow bridges. The existence of the small lake is analogous with that of the rivulets. In the month of June the melting of ice progresses rapidly; in July the ice has disappeared, but already at the end of August the freezing begins, and from September the lakes are frozen over.

"In Germania Land there are two very considerable lakes; Sælsöen (one of the largest lakes in Greenland) is 1 to 3 km broad and about 50 km long,

and Annekssöen about 1 km broad and 40 km long. Both lie concealed in deep longitudinal valleys with steep banks on either side, which valleys both of them have made foundations for considerable glaciers coming from the inland ice" (Koch). At its western end Sælsöen joins the inland ice (Storströmmen) which calves in it. "The surface of the lake is only 4—5 m above the level of the sea; the water level varies somewhat, in that during summer time it may rise presumably about one metre or more, in consequence of the melting of the snow. The depth of this lake is 116 m." (Koch). The outlet consists of the 7 km long and 60 m broad Lakseelv with its abundance of water.

"The surface of Annekssöen lies 40 m above the level of the sea. The level of the water varies as in Sælsöen and during the snow melting may rise one to two metres" (I. P. Koch). The depth in the middle is 90 m. Sæl Lake now drains towards the northwest to the moraine area immediately east of Kofoed Hansen Glacier, below which the water disappears. In former times a glacier from the inland ice filled the valley of Anneks Lake.

"In front of the glacier there was at that time a small lake, comprising the present southeast part of Annekssöen, as well as a clay plain situated to the southeast of it. In this lake the glacier river deposited the greater part of its mud, and after that continued in a south-easterly direction towards Sælsöen. This old outlet is no longer in existence at normal water level, but it is possible that it may again become active at the highest water level in Annekssöen" (Koch). There is also a possibility that the small water course which is now to be found in the southern part of the above-mentioned valley and which drains into Sæl Lake may erode itself so far backwards as to recapture Anneks Lake for Sæl Lake.

"Stormelven (Storm River) arises from five, not quite insignificant water courses, of which one or two come from the névés south-west of Cape Maria Valdemar, whereas the others rise in the boggy lowland northeast of Moskusoksefjældene. At the lower end of its course Stormelven is 50 to 250 m broad and has a strong current.

"Mörkefiordselven (Mörke Fiord River) owes its origin to two or three glacier rivers, which through large glacier gates flow out from the inland ice and empty themselves into a large marginal lake. The outlet from the marginal lake contains nearly the same quantity of water as Stormelven. The interior of Mörke Fiord is quite filled up with clay and gravel banks, originating from the river.

"All the more important rivers in Germania Land are—as we have seen—glacier rivers; in spite of their short length they can transport considerable quantities of water. Besides the above-mentioned there are still two glacier rivers, the waters of which, however, only appear in the day, after they have reached the sea. One of these has its course below Kofoed-Hansen Glacier and debouches into the south-western corner of Jökelbugt. The

other is formed from the glacier rivers of Storströmmen and Bistrup Glacier and debouches into the ice fiord of Storströmmen (Borg Fiord). It carries such great quantities of water that its tributaries under the ice must be supposed to stretch as far as the central part of Greenland. These enormous quantities of water flow out through the many sounds, in the western part of Dove Bay; the great mass of water passes, like the icebergs, between Edward Ö and Carl Heger Ö. In the narrow sounds the current in great whirlpools rushes outwards with a speed of 3 to 5 knots. The clayey waters of the glacier river could be followed as a broad brownish ribbon in Dove Bay, as far as Cape Spydodden" (I. P. Koch), which is the most southerly projection on Daniel Bruun Land (south of Helle Fiord).

The elongated island, Great Koldewey, south of Germania Land extends south of Berg Fiord, which cuts in from the west, at an altitude of 971 m. "This island has been covered by the inland ice, and considering the depth of the sea west and east of the island we may, therefore, take it for granted that in this place an ice cape has melted off, the thickness of which has been 1000—2000 m; this corresponds well with the fact that the country during the alluvial period has risen about 400 m" (Koch).

The country north of Berg Fiord is a pronouncedly moutonnéed landform, whereas the higher southern part, besides the roches moutonnées, also has typical plateau land-forms. At Træk Pass in the most southerly part of the island there are even alpine peaks. The land-forms of Little Koldewey are typical roches moutonnées.

QUEEN LOUISE LAND.

The two large glaciers, Storströmmen and Bistrup Glacier, which unite and calve under the name of Brede Glacier in the western part of Dove Bay, divide Queen Louise Land from the sea and the outer land towards the east. Queen Louise Land is beyond any doubt the most considerable nunataq area in all Greenland. It was discovered in the course of the "Danmark" Expedition and was, at a later period, investigated by Ejnar Mikkelsen and Laub in 1911—12 and by I. P. Koch, when in 1913 he crossed the inland ice at the broadest part of Greenland.

The most southerly part is Carlsbergfond Land along the north-west side of Bistrup Glacier. It is divided by Budolfi Glacier into a large southerly and a smaller northerly island. West of the northerly island lie a great number of smaller nunataqs: Dannebrog Mountains with St. Vitus' Mountain, Dronningestolen, Gefionstinderne and Helgoland. The nunataqs decrease in height the farther west one gets, and gradually become isolated rocks, Syvstjernen, Falkonerklippen, Prövestenen and, finally, Punktum.

North of Dannebrog Mountains and Carlsbergfond Land the Borg

Glacier projects towards the east between the above-mentioned areas and the mainland of Queen Louise Land, the southern part of which is called Himmerlands Hede. The most northerly part of Queen Louise Land is again split up into a number of small nunataqs, including Ymer Nunataq.

The heights in Queen Louise Land vary greatly, from a few hundred metres and, according to the measurings of Koch, the highest mountains, the

Fig. 28. Farimagsdalen in Queen Louise Land (I. P. Koch).
The prevailing land-forms in Queen Louise Land are roches moutonnées and plateaux with great valleys such as Farimagsdalen (Farimag Valley).

Gefionstinderne, are said to be about 2100 m, or in other words, some of the highest mountains in Greenland.

The greater part of Queen Louise Land consists of Precambrian rock; in the southwestern part—Carlsbergfond Land and some of the smaller nunataqs towards the west—also various sediments occur, *viz.* sandstone and slate which form horizontal layers, but, nevertheless, seem to be greatly metamorphosed. As no fossils, or at any rate only indefinable ones, have been found in the strata, it is impossible to decide to which geological pe-

riod they belong. However, several geologists suppose the strata to have been deposited within the Palæozoic period. Besides these sediments there are also older eruptives, as, for instance, diorite.

The land-forms are distinguished by great variety. The highest peaks (of about 2000 m) show pronounced alpine forms, and this particularly applies to "the western outkirts of Queen Louise Land. These nunataqs only seem to have been very little influenced by a former higher ice level. The lowest nunataqs, which only projected as much as about fifty metres through the ice, showed, it is true, a tendency to more rounded and softer land-forms, without, however, being pronounced roches moutonnées. It is not reasonable to suppose that the inland ice, in this place, has ever lain more than a couple of metres higher than it does now. The present altitude of the surface of the ice at the nunataqs is between 1800 and 1900 m. An increase in the thickness of the ice of a couple of hundred metres will, in reality, be sufficient to make Queen Louise Land disappear with the exception of the very highest peaks" (Koch).

As it will appear from what has been said above, the greater part of Queen Louise Land has land-forms which are more or less characterized by glacial erosion. Most widely distributed are the moutonnéed land-forms which occur where the nunataqs are up to 1000 and 1200 m, "though it must not be inferred from this statement that moutonnéed land-forms cannot be met with at greater altitudes. There are quite gradual transitions to the plateau landform, the altitudes of which reach 2000 m, and even in these altitudes the occurrence of examples of less pronounced moutonnéed forms is not excluded" (Koch).

Between the ice and the land there are in many places marginal lakes. "West of Dove Bay lies Randsö (ɔ: the marginal lake) at the end of Borg Glacier, bounded on the outside by L. Bistrup Glacier and Storströmmen, which join each other in this place; but also farther in at Dannebrogsfjeldene and more to the north, for instance, at Ymer Nunataq and Cape Bellevue, there are lakes. While the two are 700 and 300 m, respectively, above the level of the sea, Randsöen is only 30 m higher than Dove Bay. The marginal lakes in the central and western part of Queen Louise Land lie at an altitude of 600 to 1200 m. The water level in all of these lakes varies greatly. The lakes are filled with inrushing melting water up to the lowest pass altitude in the terrain surrounding them; now and then drainage takes place out across the inland ice and, finally, the marginal lakes may sooner or later find an outlet from the bottom of the lake in under the inland ice, and they may then become entirely emptied in so far as their bottom lies above the level of the sea.—The outlet of Randsöen across the ice to the ice-fiord of Storströmmen (Borg Fiord) consisted of an immense river bed, 15 to 20 m deep and 50 to 80 m wide" (Koch). In 1912—13 when I. P. Koch spent the winter there, this river bed was inactive, because the surface of the lake

lay considerably lower than the bottom of the river bed, and near the lake there were distinct terrace formations showing that at an earlier time it must have had a higher water level.

THE SOUTHERN FREDERIK VIII LAND.

The Southern Frederik VIII Land constitutes a rather split-up area consisting partly of some islands in the open sea, partly of some tracts of land so far removed from the sea and surrounded by huge glaciers that they must

Fig. 29. Lambert Land (I. P. Koch).
The roches moutonnées are the prevailing land-forms in the eastern part of Lambert Land, the most northerly nunataq area of Orléans Land.

rather be considered nunataqs. The area extends from Germania Land and Kofoed-Hansen Glacier in the south to Seventy-nine Fiord in the north. The most southerly of the islands is Ile de France, a 200 m high elongated island almost entirely covered with ice. Divided from Germania Land by Orléans Sound lies another fairly large (nameless) island, and north of that a row of islands, some of which are called Pariser Islands, others Franske Islands. The row of islands ends with Norske Island. West of this row of islands lies, *inter alia*, Schnauder Island. On the other side of the huge ice-filled Jökel Bay and Kofoed-Hansen Glacier comes Duke of Orléans Land, which strictly consists of 4 to 5 large nunataqs, the most northerly of which, Pic de Gerlache, attains a height of 900 m; but west of these there are some smaller nunataqs rising to heights of up to 2000 m. Zachariæ Glacier winds its way between Duke of Orléans Land and the last large nunataq, Lambert Land, which towards the north is bounded by Seventy-nine Fiord, and on the east side of which the grave of Brønlund is situated.

At Jökel Bay as well as at Seventy-nine Fiord the inland ice comes right down to the sea.

As far as is known the whole area consists of gneiss. The moutonnéed land-form prevails on all the islands in Jökel Bay and Norske Island, while a great part of Duke of Orléans' Land has typical plateau land-forms. The same applies to the western part of Lambert Land, but not to the easterly more incised projection where the moutonnéed land-form prevails.

Fig. 30. Mt. Mallemuk (Ejnar Mikkelsen).
Mt. Mallemuk (Mallemukfjæld) is the southeastern plateau-shaped cap on Holm Land.

THE NORTHERN FREDERIK VIII LAND.

The most northerly part of the east coast consists of the south-east coast of Crownprince Christian Land and extends from Seventy-nine Fiord to Northeast Foreland. It consists of two fairly large islands and two peninsulas, as well as of a few nunataqs. The most southerly island is Hovgaard Island, which at Cape Adolf Jensen attains a height of 1150 m, and which forms steep bluffs towards Djimphna Sound. On the northwest side of this sound lies Lynn Island which, in its turn, is separated by Hekla Sound from the mainland, where there are heights of up to 1800 m.

North of Djimphna Sound extends the peninsula Holm Land, which to the north is washed by Ingolf Fiord, dividing it from Amdrup Land. The greatest heights of Holm Land are 1050—1200 m, Amdrup Land being hardly more than half that height. Between Amdrup Land and Northeast

Foreland the inland ice from the interior of Crownprince Christian Land comes right down to the sea, whereas Holm Land and Hovgaard Island are covered with névés. The island consists of gneiss, while in the peninsulas there are, besides gneiss, layers of clay, slate, conglomerate, sandstone and corallaceous limestone, which lie quite regularly but with a faint dip towards the north-east. The hitherto investigated fossils show that these layers are from the Carboniferous period.

Whereas the moutonnéed land-form is widely distributed in the neighbouring southern landscapes (Orléans Land, Germania Land) it here loses a great deal of its significance as a feature of the landscape. On Hovgaard Island the pronouncedly moutonnéed land-form is confined to small areas near the coast, and farther north roches moutonnées are only met with here and there at the coasts, presumably also everywhere on islands and skerries.

Farther from the coast alpine forms become of common occurrence. They are thus to be met with on the west side of Hovgaard Island, Lynn Island, the mainland at Hekla Fiord and Ingolf Fiord, the height of the alpine land-form being from 800 to 1800 m. Holm Land and Amdrup Land are partly plateaux consisting of sandstone. The plateaux have a steep fall towards the sea, a fine example being Mt. Mallemuk on the south side of Holm Land.

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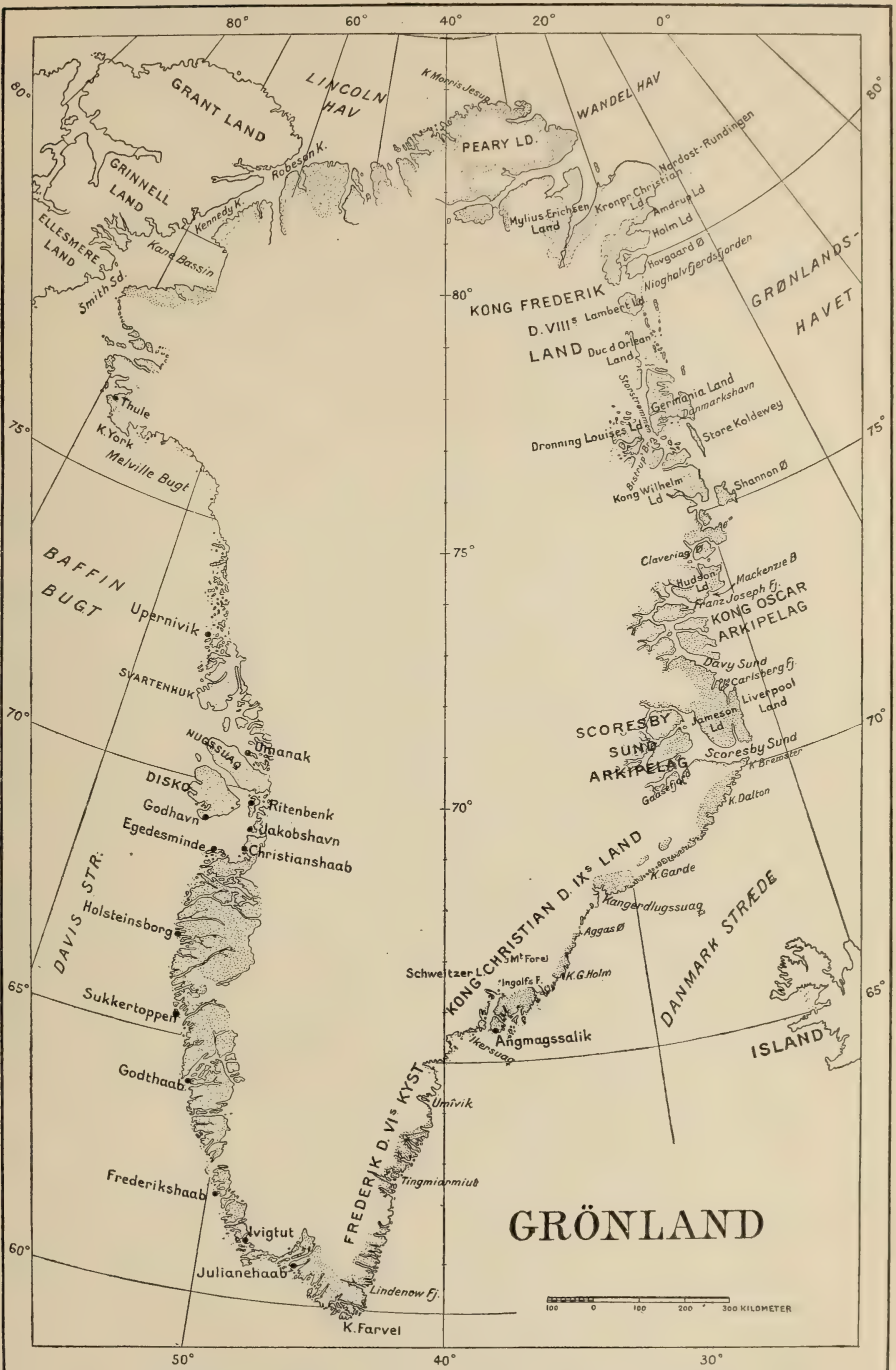

Fig. 31. Map showing the geographical regions in East Greenland.

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